The **weirdest** star in the universe p. 50

SEPTEMBER 2015

# Astronomy®

The world's best-selling astronomy magazine

# Multiverses

## SCIENCE OR SCIENCE FICTION? p. 28

**THE LATEST:** Rendezvous with an outbursting comet p. 44

Eclipse of the Super Moon p. 56

www.Astronomy.com

**BONUS ONLINE CONTENT CODE p. 4**

Vol. 43 • Issue 9

**PLUS!**

Starmus 2016 to honor Stephen Hawking p. 24

*Astronomy's* 2015 Star Products p. 60


United States

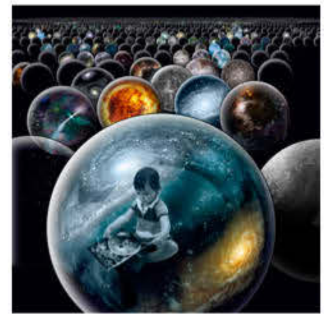
**Online Content Code: ASY1509**
Enter this code at: **www.astronomy.com/code**
to gain access to web-exclusive content

# CONTENTS

44

## SEPTEMBER 2015

VOL. 43, NO. 9



ASTRONOMY: ROEN KELLY

ON THE COVER

**Is our cosmos just one bubble in an infinite sea? Many cosmologists believe in such a multiverse even without physical evidence.**

## FEATURES



## COLUMNS



## QUANTUM GRAVITY



## IN EVERY ISSUE



Visit **Astronomy.com/toc** for bonus material — it's exclusive to *Astronomy* magazine subscribers.

*Astronomy* (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement #40010760.

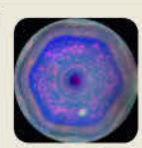
## ONLINE FAVORITES >>

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

**Dave's Universe**
The inside scoop from the editor

**Trips & Tours**
Travel the world with the staff of *Astronomy*

**Weekly Podcast**
Observing targets for all skywatchers



**50 Weirdest Objects**
Explore the most curious cosmic oddities

FROM THE **EDITOR**

BY DAVID J. EICHER

# The breathtaking pace of science

Before last year, a little piece of our knowledge of the cosmos was completely different. In the collective history of humans studying the universe around us, we had looked up close at a comet only a few times — with relatively fleeting glances and not with the kind of resolution we now have.

And then came Rosetta's rendezvous with Comet 67P/Churyumov-Gerasimenko. In August 2014, the spacecraft arrived at this periodic comet, commencing a series of maneuvers that swung it along triangular paths, staying around 30 to 60 miles (50 to 100 kilometers) from the comet's 3-mile-wide (5km) nucleus. Last November, the spacecraft detached its Philae lander, which touched down and transmitted the first detailed pictures from the surface of a comet's nucleus. After some 60 hours of operations, the lander shut down, only waking up again in June as sunlight generated power.

Meanwhile, the Rosetta spacecraft is busily streaming data and fresh images all the time. Let's set aside the incredible science we will reap from this mission — for more on that, you can read Senior Editor Richard Talcott's story, "Rendezvous with an evolving comet," beginning on p. 44.

Taken simply at a level of new imagery, the mission is completely mind-blowing. We now see the surface of a comet in unprecedented detail, in new images every week, with blocks of ice the size of football fields, boulders the size of houses, shadows splaying over cliffs rising up "skyward," and dune-like ripples, surface irregularities caused by "winds" of gas outflows. We see jets of icy water outbursts regularly in such detail that it is mind-numbing. And more and more and more.

Human beings knew about none of these features just a year ago. This comet, an icy body preserving secrets from the solar system's early days, presents a new adventure to planetary scientists all the time. Every day, the spacecraft produces new imagery and data to be analyzed that uncovers things never seen before.

I remember back several months to the fantastic excitement felt by the whole astronomy community. Now, just a few months later, many of the community seem to take these images for granted.

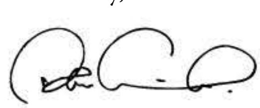
Do we really lose the sense of brand new adventure that quickly?

Thank goodness I can remember back to Martin Harwit's book *Cosmic Discovery*, which in 1981 documented that astronomers have likely uncovered only some 20 percent or so of the kinds of phenomena in the universe.

That's not to say that new discoveries will completely rewrite science. That's another disease of thinking many people seem to have. "We don't know everything; therefore, what we do know might be completely overturned in the future." That's not clear thinking, however. The law of gravitation, for example, has held up pretty well for a very long time.

Thankfully, we certainly have countless more exciting moments of discovery and exploration left ahead of us to enjoy in many ways and excite us again and again, if only for a few months at a time!

Yours truly,



David J. Eicher
Editor

*Follow the Dave's Universe blog:*
**www.Astronomy.com/davesuniverse**
*Follow Dave Eicher on Twitter:* **@deicherstar**



**Astronomy**

**Editor** David J. Eicher
**Art Director** LuAnn Williams Belter

EDITORIAL STAFF
**Senior Editors** Michael E. Bakich, Richard Talcott
**Production Editor** Karri Ferron
**Associate Editors** Eric Betz, Korey Haynes
**Editorial Associate** Valerie Penton

ART STAFF
**Senior Graphic Designer** Chuck Braasch
**Illustrator** Roen Kelly
**Production Coordinator** Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Glenn F. Chaple, Jr., Martin George, Tony Hallas, Phil Harrington, Liz Kruesi, Ray Jayawardhana, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, Sheldon Reynolds, Erika Rix, John Shibley, Raymond Shubinski

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Anne L. Kinney, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

## Kalmbach Publishing Co.

**President** Charles R. Croft
**Vice President, Editorial, Publisher** Kevin P. Keefe
**Senior Vice President, Sales & Marketing** Daniel R. Lance
**Vice President, Consumer Marketing** Nicole McGuire
**Corporate Art Director** Maureen M. Schimmel
**Art and Production Manager** Michael Soliday
**Corporate Advertising Director** Ann E. Smith
**Circulation Manager** Ken Meisinger
**Single Copy Specialist** Kim Redmond

ADVERTISING DEPARTMENT
(888) 558-1544
**Advertising Sales Manager** Jamie Rinehart
**Advertising Sales Representative**
Dina Johnston, djohnston@kalmbach.com
**Ad Services Representative**
Christa Burbank, ads@astronomy.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
**Phone** (800) 558-1544, Press 3
**Outside U.S. and Canada** (262) 796-8776, ext. 818
**Fax** (262) 798-6592
**Email** tss@kalmbach.com
**Website** www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
**Phone** (800) 533-6644; **Fax** (262) 796-1615
customerservice@kalmbach.com

SPECIAL EMAIL ADDRESSES
**Ad Sales** adsales@astronomy.com
**Ask Astro** askastro@astronomy.com
**Books** books@astronomy.com
**Letters** letters@astronomy.com
**Products** products@astronomy.com
**Reader Gallery** readergallery@astronomy.com

Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: (800) 533-6644; outside the U.S. and Canada: (262) 796-8776, ext. 421, Monday through Friday, 8:30 A.M. to 4:30 P.M. CT, Fax: (262) 796-1615; Email: customerservice@kalmbach.com. Please include your name, mailing address, and telephone number with any correspondence.

Allow 6 to 8 weeks for new subscriptions and address changes. Subscription rate: single copy: $5.99; U.S.: 1 year (12 issues) $42.95; 2 years (24 issues) $79.95; 3 years (36 issues) $114.95. Canadian: Add $12.00 postage per year. Canadian price includes GST, payable in U.S. funds. All other international subscriptions: Add $16.00 postage per year, payable in U.S. funds, drawn on a U.S. bank. Expedited delivery service surcharges: Domestic first class $30/yr; Canadian air $30/yr; International air $60/yr. BN 12271 3209 RT. Not responsible for unsolicited materials.

Follow *Astronomy*

www.twitter.com/AstronomyMag
www.facebook.com/AstronomyMagazine
plus.google.com/+astronomymagazine

Alliance for Audited Media

KALMBACH PUBLISHING CO.

Please Recycle This Magazine


MOREHEAD STATE UNIVERSITY

## Space Science Programs

- **Master of Science in Space Systems Engineering**
- **Bachelor of Science in Space Science**
- **Bachelor of Science in Physics**
- **Area of Concentration in Astrophysics**
- **Minor in Astronomy**

## Much more than a classroom.

Morehead State University proudly offers one of the only five space science degrees in the nation and boasts a 21 meter radio telescope, anechoic chamber and far field antenna test range. Recognized by *U.S. News and World Report* as one of the top public universities in the South, MSU pairs academic excellence with attractive tuition rates for both in-state and out-of-state students.

## Much more about you.

MSU delivers a strong and affordable education for friendly, ambitious students who thrive in a student-focused learning environment defined by small class sizes and faculty committed to teaching and student success.

MUCH MORE

Follow us on Facebook, Twitter, YouTube, Snapchat & Instagram.

For more information, call **800-585-6781** or visit **www.moreheadstate.edu**.

*MSU is an affirmative action, equal opportunity, educational institution.*

# QUANTUM GRAVITY

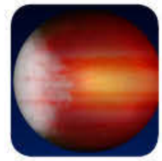
**EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .**

## HOT BYTES>>

**TRENDING TO THE TOP**

**SPACE-TIME FOAM**
NASA's high-energy telescopes tested space-time's "foaminess." It is smooth down to 1,000 times smaller than a hydrogen atom nucleus.

**FAT BLACK HOLES**
The Chandra X-ray Observatory saw black holes consume gas so rapidly that the surrounding disk puffed up into a doughnut shape.



**ALIEN WEATHER**
Kepler data revealed cloudy mornings or hot, clear afternoons on six of 14 exoplanets astronomers studied — in other words, weather.

**SNAPSHOT**

# Part-time believers not needed

Why do so many people believe in a blend of science and science fiction?

I've been fascinated by the landscape of social media posts lately. Astronomy enthusiasts are a smart bunch, but even many of those who are experienced in the details of the science seem to believe in a blend of science and science fiction.

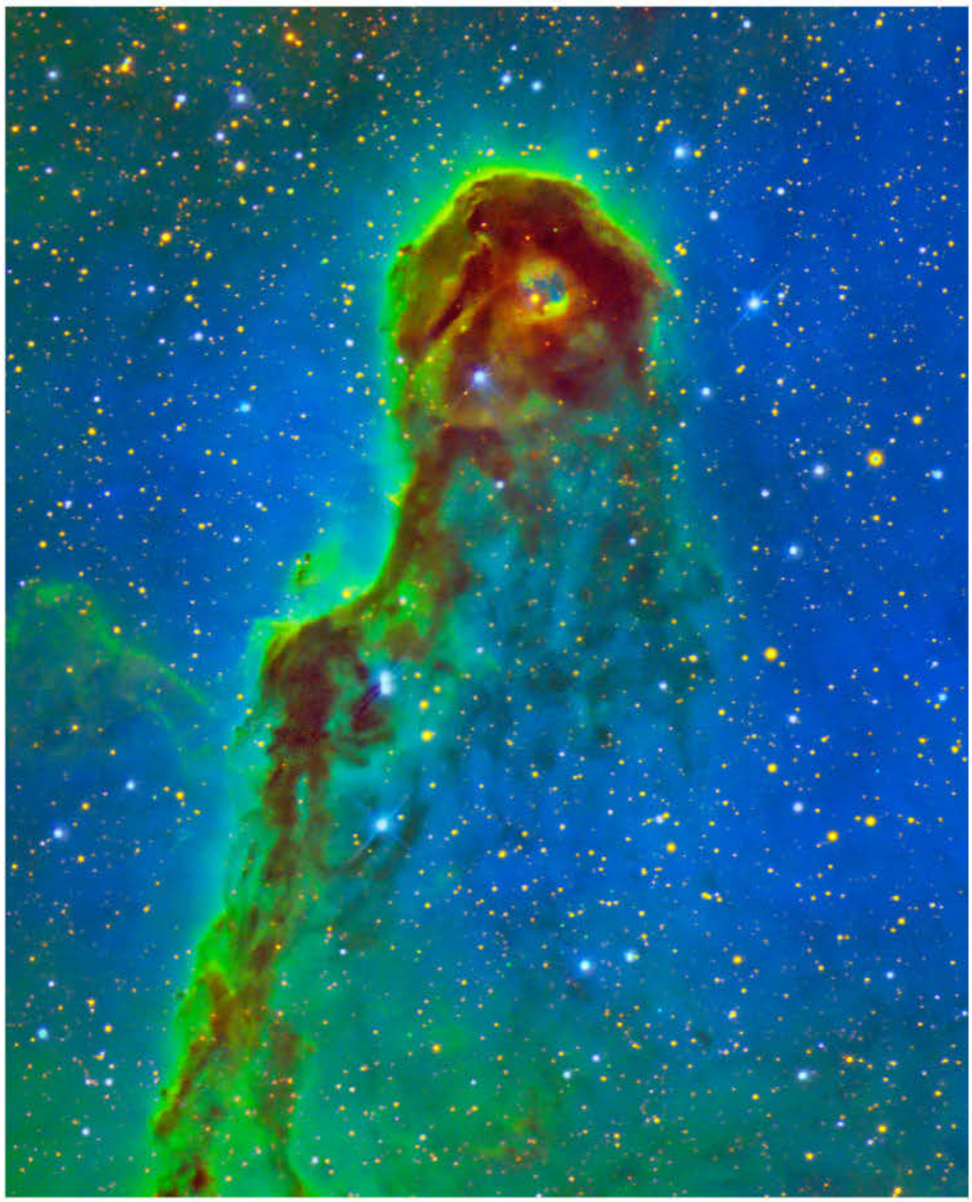
"Why couldn't we travel across the galaxy?" (Answer: Maybe we could, but the evidence — laws of matter and mass and relativity and gravitation — suggests it would be difficult, if not impossible, regardless of technological advances.)

"Why can't you travel through black holes?" (Answer: They would shred you into a string — stellar black holes at least — and therefore the whole travel idea becomes irrelevant.)

This amalgam of science and science fiction that dominates so many people's minds intrigues me. To many, what is perceived as science is really corrupted by wishful thinking.

In reality, you either believe in the principles of science or you don't. Science is a long, slowly developing process of discovery that sharpens our knowledge of how the universe works. You either buy into it and are a scientific thinker, or you are not.

Science doesn't work with part-time believers. — **David J. Eicher**



The unusual reflection nebula van den Bergh 142 lies within the larger cloud of emission nebulosity IC 1396 in Cepheus.

TONY HALLAS (VAN DEN BERGH 142); NASA/CXC/M. WEISS (SPACE-TIME FOAM, FAT BLACK HOLES); LISA ESTEVES/UNIVERSITY OF TORONTO (ALIEN WEATHER)

STRANGE**UNIVERSE**

BY BOB BERMAN

# September eclipse oddities

Let's discuss the weird stuff about this lunar event.

It's not often that nearly the whole Western Hemisphere sees a total lunar eclipse. It won't happen again until 2019. Plus, this September 27 event is in prime time; no one has to set an alarm. Only folks in Alaska and Hawaii miss totality.

Let's focus on the oft-neglected oddities.

The noticeable part of the eclipse begins at 9:07 P.M. EDT when the left side of the Moon first encounters our planet's dark inner shadow, the umbra. The next 15 minutes offer a Dali-esque surrealism. The black chunk taken out of the Moon's edge leaves the remaining lunar disk a bizarre shape that cannot be mistaken for any normal lunar phase.

Even though Earth's umbral shadow tapers like a chopstick to only about half its original size at the Moon's distance, that's still twice as big as our lone natural satellite. So the large black curve on the Moon is obviously the shadow of a bigger body. It also reveals the Moon to be nearby: Our shadow never reaches anything else. Thus the ancient Greeks proclaimed the Moon as the nearest object in the heavens, smaller than Earth, and that our planet itself is a sphere because only a globe always casts a round shadow. These were smart, observant people.

It takes 1 hour, 4 minutes for the Moon to fully push itself into our shadow. This reveals that our satellite's orbital speed propels it its own width in an hour. What other object in the known universe travels through space at the rate of one diameter per hour? None. The Moon is the only one. Not weird enough to build a religion around, but very cool.

When the partial phase has advanced about halfway, around 9:40 P.M. EDT, casual observers often think it looks like the Quarter Moon. This resemblance to something seen biweekly detracts from its strangeness. But weirdness fully returns around 10 P.M. EDT when the Moon once again adopts an appearance that resembles nothing else. This is a good time to drag children out to see something that seems straight out of a dream.

A wonderful observational project during this hourlong partial stage is to decide when the black bite taken out of the Moon changes color. Our planet always casts a reddish shadow. Our atmosphere produces a "ring of fire" — all of Earth's combined sunrises and sunsets — that surrounds the nighttime hemisphere. And yet during that first half of the partial eclipse, from 9:07 P.M. EDT until at least 9:45 P.M. EDT, our shadow looks inky black. And not just to our eyes. Photos show the same thing.

What's happening is very interesting. During this time, the Moon is still so bright that our pupils and retinas, and also camera sensors, create the proper exposure to view it clearly, thereby underexposing everything else in the vicinity. The shadow looks black because it's seriously underexposed. But at some late point in the partial eclipse, too little Moon remains. Our visual architecture adapts accordingly, increases our sensitivity, and now reveals the shadow's true coppery color.

Does this happen at different times for each person, seeing as retinas are individual? It would be great, if you have no social life and plenty of time on your hands, to make note of exactly when the eclipse shadow turns from black to red. If you send in your report, I'll save it and maybe ultimately create something that resembles science.

Also, this event unfolds during the Milky Way's most prominent display of the year, provided you're at a dark site. We'll go from a Full Moon night to a moonless one in a single hour. So, at which eclipse stage does the Milky Way materialize? When can you first see the faint stars of Pisces above the Moon? It's a rare chance to evaluate the effect of moonlight gradations on the starry heavens. If you're observing from a big city, forget this project and grab some pizza instead.

Now comes totality. It will last for 1 hour, 12 minutes. During all that time, the top of the Moon should appear much darker than the bottom. That's because only the Moon's northern limb is near the umbra's center, the shadow's murkiest part. Non-central totalities like this one typically create fascinatingly nonuniform colorations. That night, narrating such information to the intriguing neighbor who recently moved in next door might create admiration that, who knows, could result in someone falling in love with you. Let me know if a wedding ever results from this, to aid me in my ongoing efforts to distinguish fantasies from real life.

Finally, for those in the westernmost U.S. and Canada, the Moon will rise already eclipsed, providing dramatic photographic opportunities thanks to foreground objects in the same frame.

This is a *good* event, riddled with curiosities.

**NON-CENTRAL TOTALITIES LIKE THIS ONE TYPICALLY CREATE FASCINATINGLY NONUNIFORM COLORATIONS.**

*Contact me about my strange universe by visiting* **http://skymanbob.com.**

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

## FROM OUR INBOX

**Spooky shadow**

I am thankful for Stephen James O'Meara's May 2015 column (p. 14) about the spooky shadow effect. I have seen the effect many times and have wondered what was the explanation for it. Beside my bed is a small lamp with a thin black cord. When I lie in bed looking at the cord from approximately 200 millimeters away and point at the cord at half that distance, it looks like when my finger seems to touch the cord, the cord jumps onto my finger! It's always a pleasure reading O'Meara's column. — **Bent Pedersen,** Stenlille, Denmark

*We welcome your comments at* Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

**EUROPAN SEA SALT.** Scientists discovered that dark material lining features on Europa's surface could be salt from the moon's underground ocean, baked by radiation from Jupiter's strong magnetic field.

**VOLCANO WORLD.** This artist's depiction shows how thick clouds of material from eruptions on the partially molten surface of 55 Cancri e could shroud the planet in gas and dust, thus raising its temperature. NASA/JPL-CALTECH/R. HURT (IPAC)

# RAPID CHANGES ON A SUPER-EARTH

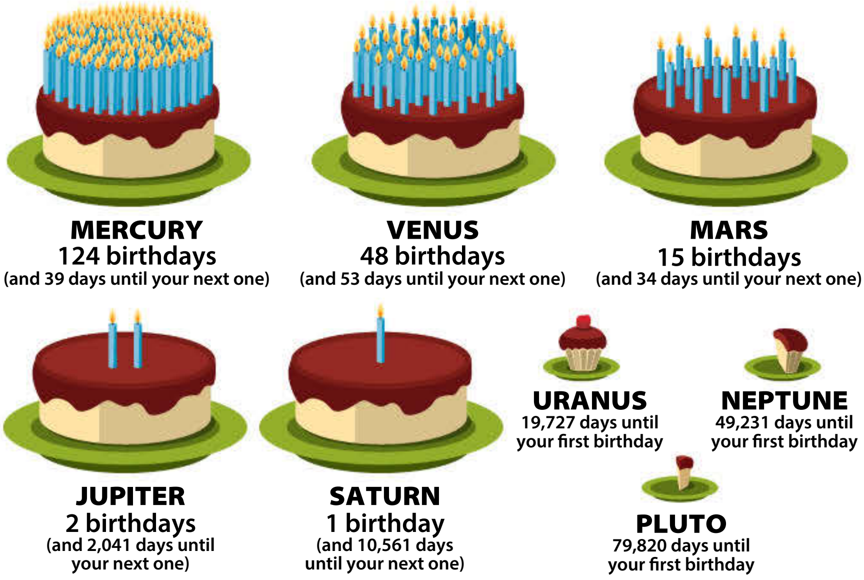
Nearby super-Earth 55 Cancri e is a dynamic place — not to mention inhospitable. This planet — twice the radius of Earth and eight times as massive — whirls around its star once every 18 hours and is tidally locked so that one side always faces the broiling sun and the other the cold of space. In the span of two years, astronomers have seen the planet's dayside temperature swing from 1,800° to 4,900° F (1,000° to 2,700° C). It marks the first time scientists have been able to discern such clear variability on an exoplanet. The researchers need more analysis before they can be sure of the cause, but their current most likely theory involves massive volcanic eruptions that smother the world in gas and dust, blocking thermal emission from the planet.

55 Cancri e's surface might be partially molten anyway, but eruptions could cause the rapid change in conditions astronomers observed with NASA's Spitzer Space Telescope. Co-author Nikku Madhusudhan explains, "The present variability is something we've never seen anywhere else, so there's no robust conventional explanation. But that's the fun in science — clues can come from unexpected quarters." His team submitted their results to *Monthly Notices of the Royal Astronomical Society.* — **Korey Haynes**

## HOW OFTEN DO MARTIANS HAVE BIRTHDAYS?

**FAST FACT**

**If we divided the year on other planets into 12 equal months, each of Mercury's months would last 7 days and 8 hours, but a month on Pluto would last 20.7 years.**




**HOW OLD?** Let's say today is your 30th birthday on Earth. How many would you have celebrated on the other planets? Because Mercury and Venus orbit the Sun faster than Earth, you would have enjoyed more birthdays on those worlds — not as many on the outer planets, however. *ASTRONOMY:* MICHAEL E. BAKICH AND ROEN KELLY

## BRIEFCASE

### COSMIC BBQ GIVES HOT START TO LIFE

DNA is the backbone of life on Earth. Explaining the double helix's origin has consumed careers since James Watson and Francis Crick announced it in 1953. Researchers from Berkeley Lab and the University of Hawaii looked at its molecular precursors and found cosmic hot spots near dying carbon-rich stars are prime places to form these nitrogen-rich molecular rings, according to an April 20 *Astrophysical Journal* paper.

### HIGH SCHOOL TEAM FINDS STRANGE PULSAR

Massive stars explode as supernovae when they die, with some leaving behind pulsars — rapidly spinning neutron stars that shoot radio waves in bright beams. Only a small number of those sit in binary star systems. And a teenage team found the widest known orbit of any such pulsar so far — once every 45 days — using data from the Green Bank Telescope. Cecilia McGough from Strasburg High School in Virginia and De'Shang Ray of Paul Laurence Dunbar High School in Baltimore made the find during a National Science Foundation workshop. It was published June 1 in *The Astrophysical Journal.*

### HUBBLE PICKS OUT A STAR NAMED NASTY

It's big, bad, and dying fast. Astronomers writing in *Monthly Notices of the Royal Astronomical Society* say the strange star, called Nasty 1, could be living through a brief transition phase experienced by massive stars. Nasty is a Wolf-Rayet star. It's much bigger than our Sun and evolves fast, shedding hydrogen outer layers and revealing a hot, bright helium-burning core. That rapid evolution also makes it hard to track its formation. Nasty is unique because it's surrounded by a pancake-like disk stretching for trillions of miles. This could indicate Wolf-Rayets form by stealing material from other stars. — **Eric Betz**

NASA/ESA

## Densest star cluster glows in infrared

**YOUNG, BRILLIANT, AND HIDDEN.** The Arches Cluster, about 25,000 light-years away toward the Milky Way center, is the densest star cluster in our galaxy. Only 2 to 4 million years old and full of massive young stars, the region is swamped with gas enriched by earlier supernova explosions and thick dust that hides the starlight from visible-light instruments. The Hubble Space Telescope's infrared camera spied through the murk to take the above image. While the Sun's nearest stellar neighbor is just over 4 light-years away, the Arches Cluster is only 1 light-year across. Yet in that cosmically tiny space, the Arches packs in thousands of stars, including over 150 of the brightest stars in the galaxy, up to 100 times the Sun's mass, that will die in supernova explosions. — **K. H.**

**ANCIENT MAGNETISM.** The recently deceased MESSENGER spacecraft used its last days buzzing Mercury's surface to uncover evidence for the planet's magnetic field arising over 3.7 billion years ago.

# Curtains of ice spew from Enceladus' salty seas

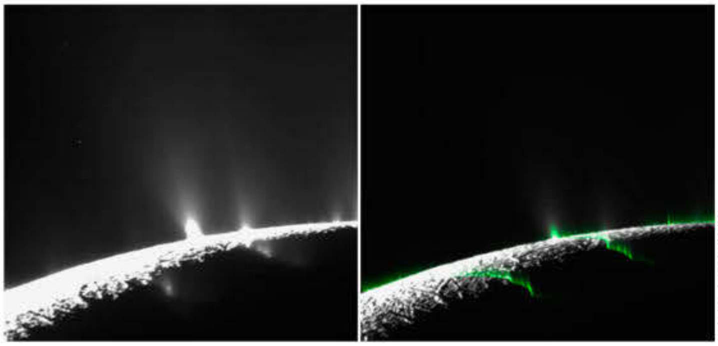
Scientists suspect Saturn's moon Enceladus has a liquid ocean beneath its global shell of ice, with volcanism that drives geyser-like eruptions. But new research shows the distinct jets seen shooting up from the surface might have been an optical illusion, according to scientists on NASA's Cassini mission team. Instead, their evidence indicates curtain eruptions occur along massive fractures called "tiger stripes" on the moon's south pole. These eruptions look like jets in images because the fractures are squiggly instead of straight.

"The viewing direction plays an important role in where the phantom jets appear," says the Planetary Science Institute's Joseph Spitale, who is lead author on the May 7 *Nature* paper. "If you rotate your perspective around Enceladus' south pole, such jets would seem to appear and disappear."

His group paired Cassini observations with computer models of how the curtains would appear and found such eruptions explain most, but not all, of the jets observed.

Other research summarized in May by the journal *Geochimica et Cosmochimica Acta* analyzed the pH of those plumes and found a salty surprise. The water packs an ammonia-like alkaline pH around 11 or 12.

What's more, Enceladus' oceans have the same salt content as Earth's but hold higher levels of sodium carbonate closer to our planet's soda lakes, including Mono Lake in California. — **E. B.**



NASA/JPL-CALTECH/SSI/PPI

**ICY ERUPTIONS.** This simulation shows how curtains of fine icy particles could erupt from fractures in the surface of Saturn's moon Enceladus and appear as distinct jets.

# Supernova slams star, helps explain standard candles

On May 3, 2014, the intermediate Palomar Transient Factory (iPTF), a robotic observatory, spotted a strong ultraviolet light source from the vicinity of a galaxy in the Coma Cluster 300 million light-years away. Astronomers checked the scope's observations and confirmed nothing was there the previous night. They'd caught a supernova in action.

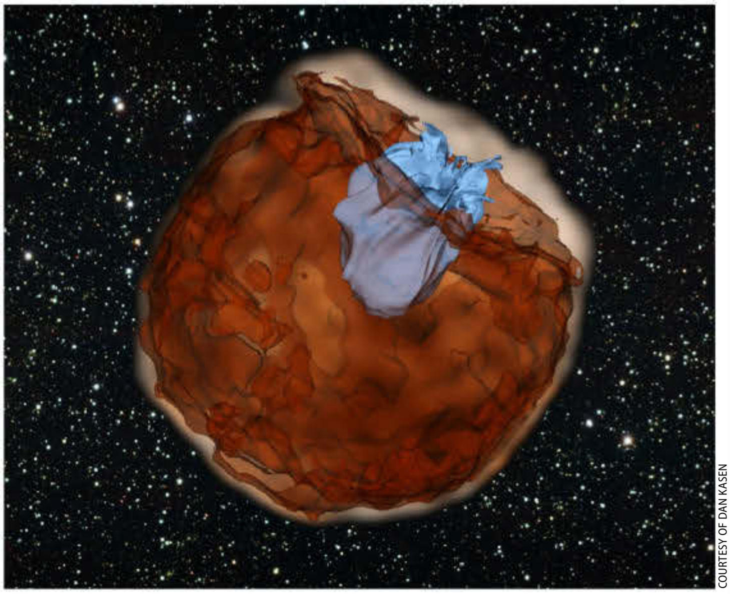
For decades, the uniform brightness of type Ia supernovae has earned these exploding objects an empirical place as "standard candles" for measuring distances and the speed of cosmic expansion. And astronomers know the process starts when at least one white dwarf — the core of a dead star — explodes in a binary system. But beyond that, type Ia origins remain mysterious. Does the supernova ignite as the two stars merge, known as double degeneracy? Or is it spawned by a white dwarf gorging material from a red giant until the dwarf explodes via so-called single degeneracy?

In hopes of better understanding, the iPTF astronomers immediately enlisted X-ray and ultraviolet instruments on NASA's Swift space telescope to watch as the strong ultraviolet signal rapidly faded. The Las Cumbres Observatory Global Telescope Network turned to watch the explosion as well.

"Hot blue supernovae are not supposed to happen in old dead galaxies," says Yi Cao, a graduate student at the California Institute of Technology who was first author of the May 21 *Nature* paper detailing the find. "And yet, as our robotic telescopes gathered the data, we watched in amazement as the blue supernova morphed into a type Ia supernova."

The team says the find gives evidence for the single-degeneracy model. They suspect that as the white dwarf star exploded, the ejecta slammed into its binary companion star and heated the surrounding material. That heat peaks in the UV and explains the unexpected signal. More importantly, their results show that type Ia supernovae might have uniform brightness but likely don't share uniform origin stories. Rather than rule out one theory for another, astronomers think the discovery indicates both are possible.

"The news is that it seems that both sets of theoretical models are right, and there are two very different kinds of type Ia supernovae," says Caltech's Sterl Phinney. — **E. B.**



COURTESY OF DAN KASEN

**SUPERNOVA SMASHUP.** When a white dwarf explodes (brown), the ejecta slams into its companion star (blue), and the violent collision sends out an ultraviolet pulse.

## QUICK TAKES

### GALACTIC DEATH
Astronomers found that most galaxies die slowly. Instead of expelling gas and shutting off star formation all at once, galaxies instead steadily eat up gas until they run out of fuel.

### DELTA'S FRIEND
Variable star Delta Cephei, prototype for a well-known class of variable stars called Cepheids, has a smaller companion, undetected for the 230 years astronomers have studied its partner.

### SUPERFLARE STARS
A team of Japanese astronomers found Sun-like stars with large sunspots that host superflares, with energies 10–10,000 times greater than the Sun's largest flares.

### FLUFFY GALAXIES
Astronomers used the Keck Observatory in Hawaii to find "fluffy" galaxies as big as the Milky Way in size but containing only 1 percent of the stars in our galaxy.

### WISE FIND
NASA's WISE telescope discovered a new record-setting brightest galaxy. Most of the brightness is probably due to material lighting up as it falls into the galaxy's central supermassive black hole.

### ALMA EYES MIRA
ALMA saw a massive flare on the well-known red giant star Mira, which is close enough for the telescope array to see surface details.

### 10,000 TELESCOPES
Jean and Ric Edelman donated funds for 10,000 Galileoscopes — small scopes designed for classroom use — to be distributed in U.S. schools.

### ALIEN MOONS
Scientists announced that alien moons — larger than Mars, orbiting planets as large as Jupiter — might make the best targets when hunting for extraterrestrial life.

### EUROPAN TOOLS
NASA selected nine out of 33 proposed science instruments for a mission to explore Jupiter's moon Europa, with an emphasis on habitability. The mission is scheduled to launch in the 2020s. — **K. H.**

FOR**YOUR**CONSIDERATION

BY JEFF HESTER

# Brains in a box

Pleistocene thinking in a post-Pleistocene world.

Your ancestors had to do four things well. They had to eat. They had to avoid being eaten. They had to cope with the elements. And they had to reproduce. If they had failed at any of those, you wouldn't be here.

There are lots of ways to tackle those challenges. Some species went the route of sharp claws and big teeth. Others learned to hide. Still others just bred faster than predators could eat.

Evolution took humans down a different path; we're smart, and we work together. Evolution provided us with curiosity, tool-using intelligence, adaptability, and the capacity for language and culture. As our brains got bigger and more complex, we fared very well, indeed.

Now we are on top of the heap. Hallelujah! We won!

Well, sort of. Big brains are great for thinking, but they have some serious evolutionary downsides. For one thing, that 3-pound (1.4 kilograms) tangle of neurons inside your skull is expensive to feed! While making up only a few percent of your body mass, your brain uses something like 20 percent of the calories you burn.

Physical size is another problem. Human childbirth is both dangerous and painful, and we are born totally helpless. That is all due to the troublesome mechanics of squeezing such a big brain through a pelvis.

So yes, that fancy pattern recognition engine between our ears is nice to have. But evolution favored brains that were absolutely no bigger than they needed to be. You might say we have Goldilocks brains. Smart enough, but not too smart, our brains fit in a box that was just right for the world where they evolved.

If you want to see one of the walls of that box, look at the boundary between classical and modern physics. We're naturals at throwing and catching a baseball, but get anywhere near the speed of light, and things get seriously counterintuitive. Try to think about elementary particles, and it's even worse. As Niels Bohr famously said, "Anyone who is not shocked by quantum theory has not understood it!"

Relativity and quantum physics are hard to think about for a very straightforward reason. Thinking like that didn't help your great-many-times-removed grandparents find their next meal!

Yet we *have* broken outside that box. We know about cosmology and curved space-time. We know about wave functions.

## FROM OUR INBOX

### Leave God out

I enjoyed your coverage of the Starmus Festival in the May 2015 issue (p. 54) of *Astronomy*. I agree with Editor David J. Eicher's concern about the general lack of public support for science. Unfortunately, the quote from Stephen Hawking, "there is no god," was unhelpful, and it would probably have been better if Hawking's personal religious views were omitted from the article. **— Warren Morrison,** Cavan, Ontario



Our brains evolved to keep us alive in a time when the law was "eat or be eaten." It is up to us to evolve our thinking if we want to survive today's more rapid rate of change.

Kicking down those walls wasn't easy. It meant redefining our very concept of knowledge. It meant replacing comfortable modes of thought with bold creativity and cold reason. It meant following observation and experiment where they led, regardless of whether we liked the destination.

Humans will never grasp electrons or the Big Bang in the same visceral way we grasp notions like "day" or "rock," but intellectually we got there! And when we did, it changed the world.

The difference between billiard balls and quarks is hardly the only place we run up against the limitations of our programming. For most of our evolutionary history, generation after generation faced the same basic challenges. So if your ancestors' solutions worked for them, there was a pretty good chance they would work for you too. Your tribe's very existence was recommendation enough for its way of doing things.

In that world, it paid to be conservative because conservative *worked*. Questioning the status quo truly was dangerous. "Better" can be the enemy of "good enough," and while thinking was great, try to be too clever, and you might not survive to become anybody's ancestor!

So evolution added to the box around our brains. It's difficult to break free of tradition, groupthink, conformity, and tribalism because they are hard-wired in. Which is all well and good, were it not for the fact that we don't live in the Pleistocene anymore.

When faced with a challenge, millions of years of evolution scream at us to hold tight to traditional beliefs and behaviors. But heeding that cry in today's world could be our downfall. Modern humans see more change in a month than our ancestors saw in many lifetimes. Fighting a rearguard action against an inexorable tide of changing social, economic, and technical realities is a pathway to irrelevance — or worse.

The stakes are high. Today our species shares a globally connected and interdependent planet. Huddling with our tribe and snarling at the shadows might scare off a lion hiding in the bushes, but threats like overpopulation, global warming, or the ecosystem's destruction don't frighten so easily.

The human brain came of age inside a box. It also evolved the ability to break out of that box when it needed to. We've done it before. But taking control of our own drives and instincts cuts a lot closer to the bone than rethinking Newtonian physics.

Our fate is in our hands. Time will tell if we are up to the challenge.

*Jeff Hester is a keynote speaker, coach, and astrophysicist. Follow his thoughts at* **jeff-hester.com.**

BROWSE THE "FOR YOUR CONSIDERATION" ARCHIVE AT **www.Astronomy.com/Hester.**

**SINISTER MATTER.** Scientists discovered a "left-handed" twisting magnetic field that could explain why most of the universe today comprises left-handed normal matter instead of right-handed antimatter.

# THE FUTURE OF HAWAIIAN ASTRONOMY

**CONTESTED LAND.** Protests over land use on Mauna Kea in Hawaii came to a head this spring when construction officially started on the Thirty Meter Telescope. The telescope will move forward as planned, but it will be the last new site cleared on the mountain's summit. TMT INTERNATIONAL OBSERVATORY

This year has seen a storm of protests over the upcoming $1.4 billion Thirty Meter Telescope (TMT) construction near the summit of Hawaii's Mauna Kea. The Big Island's central peak is the premier observing location in the Northern Hemisphere — perhaps in the world — and is also deeply connected to Native Hawaiian culture and traditions. Since the University of Hawaii's 2.2-meter telescope saw first light there in 1970, Mauna Kea has amassed 13 telescopes owned by research institutions from around the globe with science spanning the radio to optical wavelengths.

The site's dark skies and clear weather are unparalleled for astronomical use, but many Native Hawaiians and conservationists argue that the mountain peak has surpassing importance as a cultural and natural site that insensitive scientific activities and especially the latest round of construction are destroying. Hawaiians opposing what they see as further desecration of sacred land have protested TMT's placement since its site selection.

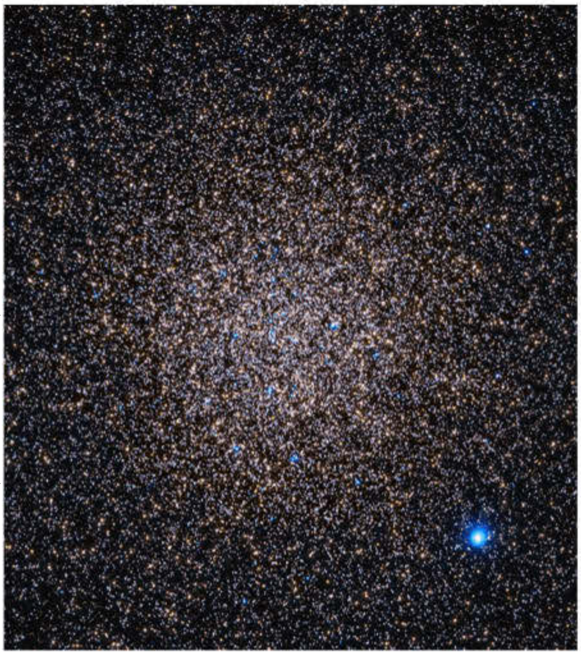
At the end of March, they blocked construction access to Mauna Kea's summit, resulting in dozens of arrests and prompting Hawaii's governor, David Ige, to issue a construction moratorium April 7 while the groups involved — the state of Hawaii, the TMT Observatory Corporation, the University of Hawaii (who manages the land), Hawaiian cultural groups, and others — searched for an agreeable resolution.

On May 26, Ige announced a compromise: Construction on TMT would resume, but 25 percent of the telescopes currently on the mountain (all of which are active) must be dismantled before the completion of TMT, and no new "footprints" can be established, meaning all future telescopes must be built on pre-existing sites. An older plan set in 2010 also outlined this goal, but the university will make it legally binding. The first telescope to cease operations will be the California Institute of Technology's Submillimeter Observatory, effective this month. The University of Hawaii promised to complete a plan for the additional observatories to be closed by the end of the year.

In his statement, Ige explicitly upheld TMT's legal adherence (including completion of an environmental impact study) and right to proceed but also acknowledged that "in many ways, we have failed the mountain." The state of Hawaii leases the land under and around the telescopes — known as the Mauna Kea Science Reserve — to the University of Hawaii, who manages its use and is tasked with stewardship of the mountain. In light of concerns over this stewardship, when the university's lease expires in 2033, more than 40 of the 45 acres that constitutes the reserve will return to the Department of Land and Natural Resources (DLNR). The DLNR also will extend the lease (for the land immediately under the observatory facilities) for "substantially less" than the original 65-year term.

TMT is only one of the upcoming generation of extremely large ground-based telescopes, which includes the Giant Magellan Telescope (GMT, composed of seven mirrors spanning 25 meters) and the European Extremely Large Telescope (E-ELT, with a 39-meter primary mirror), both to be built in Chile. The GMT moved into its construction phase June 3 and expects to see first light in 2021, and the E-ELT is scheduled to begin science operations in 2024. **— K. H.**

## Hubble spots migrating white dwarfs



NASA/ESA/H. RICHER AND J. HEYL (UNIVERSITY OF BRITISH COLUMBIA)

**LATER MASS LOSS.** Using the Hubble Space Telescope to study globular cluster 47 Tucanae in ultraviolet light, astronomers for the first time have captured snapshots of the 40-million-year migration of stellar remnant white dwarfs (visible as tiny bright blue specks in this image) from the core of the dense star cluster to its outskirts as they slowly lose mass. The surprise came when the study, whose results appeared in the May 1 issue of *The Astrophysical Journal*, revealed relatively young white dwarfs just beginning their journey from the center. Previously, astronomers thought that stars lost most of their mass 100 million years before becoming white dwarfs. Yet the discovery of young stellar remnants still near the cluster center indicates that stars actually lose only 40 to 50 percent of their mass just 10 million years before entering the white dwarf phase; otherwise, such young white dwarfs would have been found farther from the cluster's heart. **— Karri Ferron**

**TINY STAR, BIG PLANET.** Scientists, with the help of an amateur observer, discovered a puffy Saturn-mass planet orbiting close to its tiny, cool star, HATS-6.


## 25 years ago in *Astronomy*

In *Astronomy*'s September 1990 issue, science writer Damond Benningfield explored where short-period comets come from, addressing the first research to indicate a Kuiper Belt of icy objects past Neptune. In two more years, 1992 $QB_1$, the second Pluto, would help confirm the theory.


## 10 years ago in *Astronomy*

In September 2005, astronomer and current New Horizons head S. Alan Stern wrote about evidence that comets are not pristine bodies as once believed. Ultraviolet radiation, cosmic rays, and internal heat can darken surfaces, alter deep chemical bonds, and evaporate ices. — **E. B.**

**13.17 billion years old**

Age of the most distant galaxy as measured by the Keck I Telescope in Hawaii.

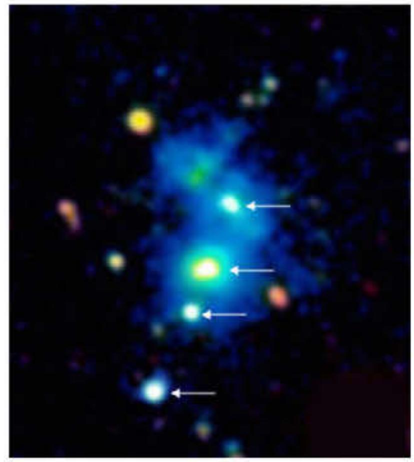
# Quasar quartet found in dense corner of the universe

Astronomers using the W. M. Keck Observatory in Hawaii stumbled across a group of quasars tucked away in a dense corner of our universe. Quasars form as matter falls onto the supermassive black holes at the centers of galaxies. When the black holes feast, these rare active objects become the brightest in our universe for a brief period of time.

So finding this fearsome foursome so close together took the group by surprise. No one's ever spotted such a quartet before. The team estimates a one in 10 million chance of this occurring randomly. Instead, the group found clues in the quasars' environment. The four active galaxies are surrounded by an incredible nebula of hydrogen some 1 million light-years across, and the whole system sits in a rare area densely packed with matter.

"There are several hundred times more galaxies in this region than you would expect to see at these distances," said University of California, Santa Cruz, professor J. Xavier Prochaska, who worked as principal investigator of the observations.

The discovery appeared May 15 in *Science* and was led by Joseph Hennawi of the Max Planck Institute for Astronomy. — **E. B.**



HENNAWI & ARRIGONI-BATTAIA, MPIA

**FEARSOME FOURSOME.** Astronomers think these four quasars are too close together for them to have formed there by chance. Some other force must be at work.

ESA/HUBBLE/L. CALÇADA (ESO)

**JETSETTING GALAXIES.** Powerful jets streaming away from black holes, as illustrated here, form as the result of recent galactic mergers, according to new research from Hubble.

# Merging galaxies spark powerful jets

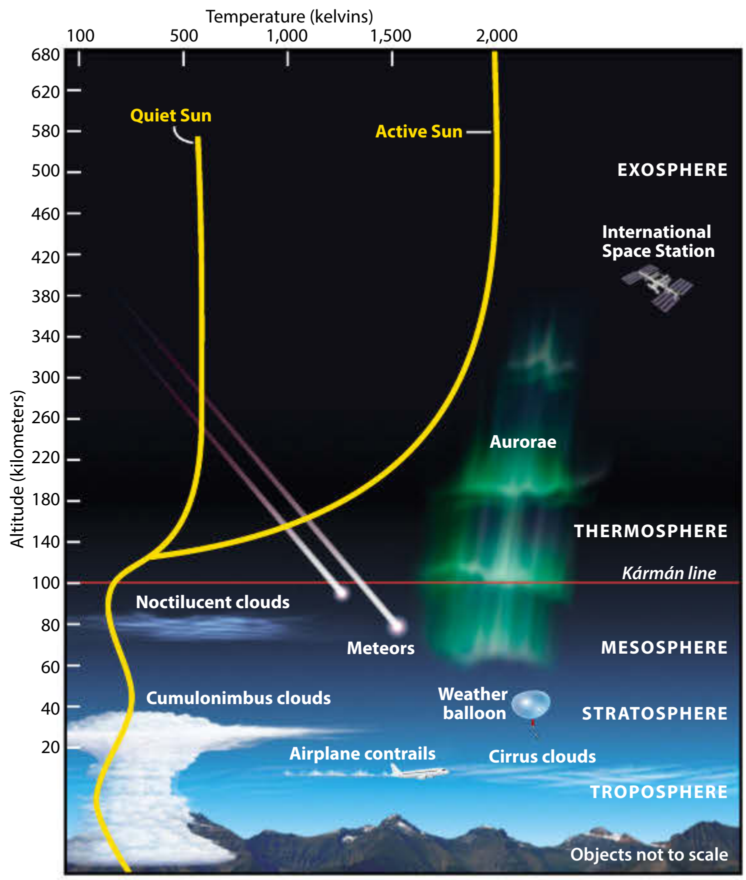
Astronomers used data from the Hubble Space Telescope to prove conclusively that active galactic nuclei — extremely bright galactic centers powered by feeding black holes — with relativistic jets are the result of merging galaxies. The team did not see signs of the jets, material ejected perpendicular to the swirling disk of material around the black hole at nearly the speed of light, in all merging galaxies, but all galaxies with jets showed signs of recent collisions.

This implies that mergers are only one of multiple requirements for forming these high-powered streams of material. The team plans to use ALMA to expand the survey and hunt for these additional causes in the future. Their study was published June 20 in *The Astrophysical Journal*. — **K. H.**

**FAST FACT**

**Astronomers estimate some 60 tons of cosmic dust reach Earth's surface each day, helping create noctilucent clouds and fertilize phytoplankton.**

## EARTH'S DYNAMIC ATMOSPHERE




**THE SPACE BEFORE SPACE.** There's a lot going on between Earth's surface and the Kármán line — the boundary of our atmosphere and outer space. And while those heights can seem vast to a stargazer, even the International Space Station's height is roughly equivalent to the distance between New York City and Boston. *ASTRONOMY*: ERIC BETZ, ROEN KELLY, AND JAY SMITH

SECRET**SKY**

BY STEPHEN JAMES O'MEARA

# Rainy eclipse

The author reflects on an eclipse in a puddle.

***EDITOR'S NOTE:*** *Because this column recounts an observation of the Sun without a filter, we sought the opinion of B. Ralph Chou, professor emeritus of the School of Optometry and Vision Science at the University of Waterloo, one of the foremost researchers in the field of eye safety. In his reply, he said, "The technique of observing the Sun by its reflection off water dates back several thousand years. It is quite safe because the reflection in the visible spectrum is of much lower intensity and the reflected flux of ultraviolet and infrared radiation is extremely small and therefore of no concern. Although the Sun's image is bright, it is not hazardous for the brief observing times that the author used."*

I almost made it to the remote Norwegian island of Svalbard on March 19, 2015, to view the next day's total eclipse of the Sun. But a tight connection, last flight, and other logistical nightmares ended my travels that day. So, I settled into a hotel in Oslo, where I awoke on eclipse morning to a gray sky and lots of drizzle.

As the time of first contact neared, however, breaks in the weather allowed glimpses of the Sun. So outside I went, armed with a camera and a solar filter — the latter of which I seldom used because I happily shared it with hotel staff and guests who were thrilled to watch as the Moon covered 86 percent of the Sun at maximum. At one point, I happened to look down at my feet and into a puddle where I saw the eclipsed Sun, naturally filtered by the water, surrounded by a glowing corona (an atmospheric one).

## A ripple effect

The puddle acted like a mirror, reflecting the image to my eyes. The dark asphalt background combined with the thinning cloud acted as a natural filter (absorbing and scattering light), reducing the Sun's brilliance by some 50-fold and making the eclipse comfortable to observe without optical aid.

As I watched the Moon's dark silhouette sink its teeth into the solar surface, I noticed it had an irregular shape. This distortion is common to reflections tilted to the plane of sight. Imperfections in the water's surface distorted the event, which I found fascinating. The minute undulations, some barely visible, acted like another layer of tilted mirrors creating all manner of optical effects, including crescents and other shapes in a glitter path and, at times, a crisp polygonal edge to the Moon's silhouette.

## Muddle in a puddle

The puddle view also revealed a beautiful aureole — the innermost ring of the colorful atmospheric corona. It consisted of a pale blue inner region (indicating scattering of blue light by tiny water droplets in the cloud) fringed by a smoky orange ring.

Usually, the aureole is indeed concentric with the Sun's disk. But during a partial solar eclipse, the ring is concentric with the illuminated crescent, making the colored sphere appear oddly lopsided. You can view this effect more frequently when viewing a lunar crescent through passing altocumulus clouds.

## Smoke & mirrors

Finally, I got a shudder when I saw what appeared to be a reversed aureole effect. When looking at the eclipsed Sun in the puddle, I saw the greatest extent of the aureole on the side of the eclipsed Sun when it should have been the other way around. It took but a moment for me to realize that this was an illusion created by a crescent-shaped cloud edge, almost concentric with the Sun, which obscured the greater half of the aureole.

The effect recalled a telescopic observation of the Skull Nebula (NGC 246), a planetary nebula in Cetus. It has a central star that appears off-center because the nebula's eastern rim is exceedingly faint and fully one-quarter of the shell is all but invisible through small telescopes.

As always, go gently into the night (or the shadow-darkened day, if that applies), and let me know what you observe at sjomeara31@gmail.com.

During the eclipse, an aureole — the innermost ring of the image's corona — appeared off-center. These pictures show a large asymmetrical aureole around a roughly 60 percent eclipsed Sun (left) and a small asymmetrical corona around a roughly 40 percent waxing crescent Moon. ALL PHOTOS: STEPHEN JAMES O'MEARA

When the author viewed the reflected image of the partially eclipsed Sun, he noted its irregular shape and several other effects.

This photograph shows a sight that initially surprised the author. Here, most of the aureole lies on the side of the Sun covered by the Moon, and not the reverse as he expected.

## COSMIC WORLD

*A look at the best and the worst that astronomy and space science have to offer.* **by Eric Betz**

**Cold as space** — **Supernova hot**

**No scientists**

NASA head Charles Bolden chides a House committee playing politics with climate science after it shifts $300 million from Earth studies to space travel. Let's hope the Mars colony fits 7 billion.

**What warp drive?**

The Web goes wild for warp drives as an obscure NASA lab claims to test a propulsionless drive under vacuum. The agency settles things down with a refresher on conservation of momentum.

**DIY detector**

A team of undergrads from Missouri Southern State builds a subatomic particle detector with $500 in off-the-shelf camera parts. The budding MacGyvers plan to measure muons.

**Buoyant barista**

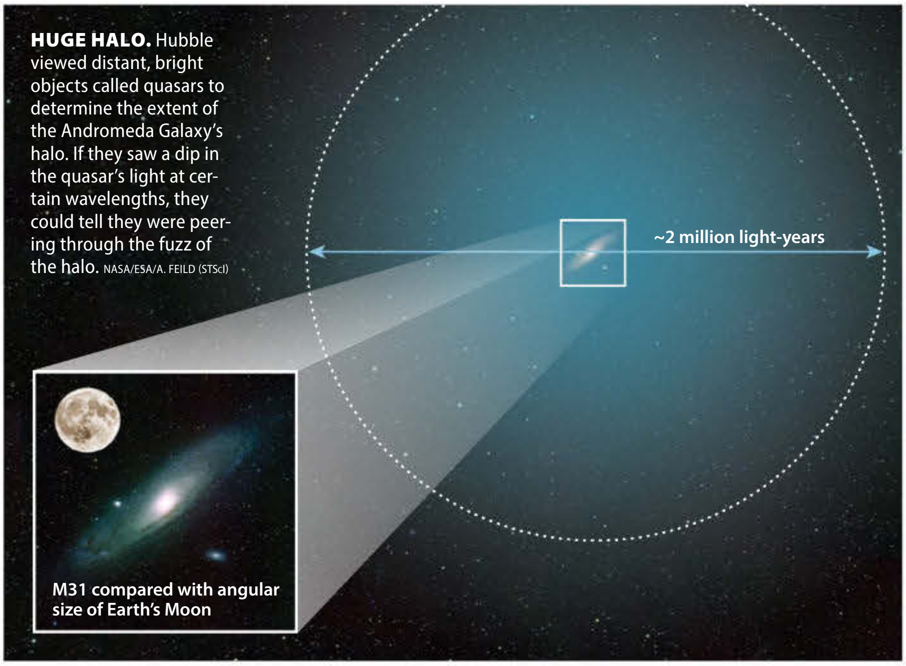
With the Italian Space Agency's successful delivery of ISSpresso, astronaut Samantha Cristoforetti wears a *Star Trek* uniform as she sips the first fresh coffee in orbit. Space is now survivable long term.

NO SCIENTISTS (NASA); WHAT WARP DRIVE? (SPR, LTD); ASTRONOMY: ROEN KELLY (DIY DETECTOR); BUOYANT BARISTA (ISA)

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

ASTRONEWS **BALANCING ACT.** Rosetta has seen a 100-foot-wide (30 meters) boulder on Comet 67P/Churyumov-Gerasimenko balancing on a narrow rim.

# Andromeda gets a lot bigger



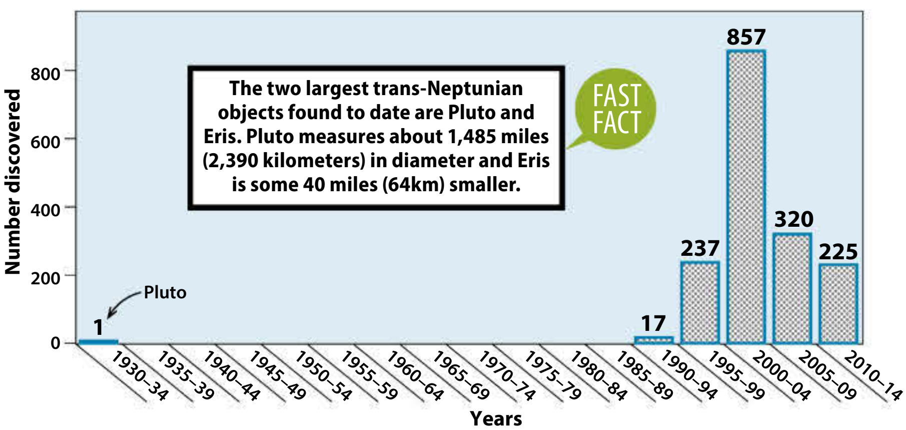
**HUGE HALO.** Hubble viewed distant, bright objects called quasars to determine the extent of the Andromeda Galaxy's halo. If they saw a dip in the quasar's light at certain wavelengths, they could tell they were peering through the fuzz of the halo. NASA/ESA/A. FEILD (STScI)

The massive and nearby Andromeda Galaxy (M31) has a halo even bigger than astronomers thought, about six times larger and 1,000 times more massive. This halo of gas is diffuse yet so large that it contains the mass of half the stars in the galaxy.

Scientists used the Hubble Space Telescope to study how the nearly invisible gas of the halo blocks light from background quasars, more distant galaxies that shine brightly as gas falls into their central black holes. Normally, these types of studies can use only one quasar per galaxy, but the close proximity of M31 means this galaxy sprawls across a length of sky six times wider than the size of the Full Moon, allowing astronomers to use 18 quasars in this case and giving them unprecedented accuracy.

Scientists have known for a while now that Andromeda and the Milky Way are on a collision course, speeding toward each other through the 2.5 million light-years that currently separate them. The new measurements for Andromeda's halo mean our large neighbor actually extends nearly halfway across that distance already. The halos of the two galaxies will begin to interact much sooner than the 4-billion-year countdown until their stellar populations begin to merge. The study was published May 10 in *The Astrophysical Journal*. — **K. H.**

## THE SOLAR SYSTEM BEYOND NEPTUNE




**TRANS-NEPTUNIAN OBJECTS.** When Clyde Tombaugh discovered Pluto in 1930, scientists thought they had found a missing planet. This distant world remained the only known non-comet beyond Neptune until David Jewitt and Jane Luu found 1992 $QB_1$ 62 years later. By the end of 2014, astronomers had detected more than 1,500 trans-Neptunian objects, loosely defined as bodies whose average distance from the Sun is greater than Neptune's. Much of the apparent drop-off in recent discoveries stems from search teams that don't report new finds until they observe an object at multiple appearances. *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

# ASTROCONFIDENTIAL BY KARRI FERRON

**FAST FACT** Nanoflares are spontaneous solar heating bursts that each reach some 18 million degrees F (10 million degrees C).

## WHAT HEATS THE SUN'S OUTER ATMOSPHERE?

### James A. Klimchuk
Astrophysicist in the Heliophysics Division at NASA Goddard Space Flight Center, Greenbelt, Maryland

COURTESY JAMES A. KLIMCHUK

At several million kelvins, the Sun's outer atmosphere, called the corona, is a thousand times hotter than the underlying solar surface. Understanding what heats the corona to its extreme temperatures is one of the cornerstone questions in space science. New evidence has revealed that coronal heating takes the form of impulsive energy bursts called nanoflares. Although puny by solar standards, each one is the equivalent of a 50-megaton hydrogen bomb, the largest ever detonated on Earth. Millions of nanoflares occur every second across the Sun, and together they pack a real wallop.

Nanoflares have been difficult to study because we are unable to observe individual occurrences. Even with the resolution of our most powerful telescopes, we are stuck seeing multiple overlapping events along the line of sight. As a consequence, progress has had to rely on a combination of observations and theoretical modeling. By comparing what we see with what we expect to see based on computer simulations, we can infer the properties of the energy release. Recently, we have detected faint emission from superhot plasma (highly ionized gas). This only can be produced by nanoflares, and we consider it to be the "smoking gun."

So, what is a nanoflare? That's still an open question, but the most likely explanation is that it represents the sudden breaking of stressed magnetic fields that extend upward from the solar surface and permeate the corona. Turbulent motions at the surface cause the coronal fields to become tangled and twisted much like rubber bands. Eventually, the fields break and release bursts of energy — nanoflares — in a process called magnetic reconnection. It is at the heart of many different phenomena occurring throughout the solar system and the universe. By studying nanoflares, we hope to learn more about these other phenomena as well.

# ASTRONEWS

**EATING HABITS.** Astronomers read galaxy NGC 1512's past eating habits in the processed clumps of gas scattered across its face, material that it must have absorbed from other smaller galaxies.

## NASA's next Mars lander readies for launch

NASA/JPL-CALTECH/LOCKHEED MARTIN

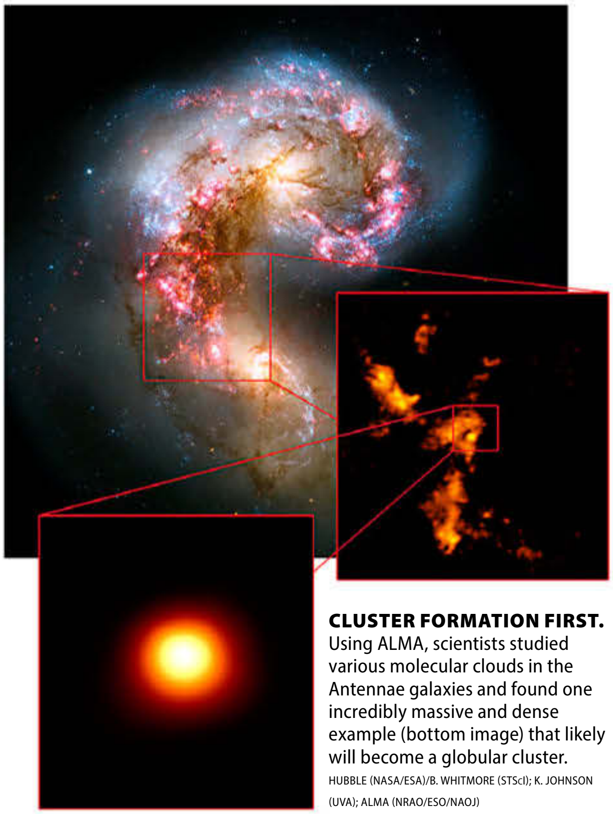
**BEST PRACTICE.** This is how NASA's next Mars lander, InSight, will look when it deploys on the Red Planet's surface one year from now and begins to study its crust, mantle, and core for the first time. Lockheed Martin Space Systems in Denver has finished building the spacecraft and moved on to the final testing phase ahead of the March 2016 launch. InSight deployed its solar panels during tests April 30, and engineers entered a seven-month environmental testing phase that will expose the car-sized craft to space-like hazards. NASA also announced plans to deploy CubeSats as InSight enters orbit at Mars and use the tiny instruments to observe the landing. If it succeeds, the lander could help tell astronomers how rocky planets form. — **E. B.**

**GRAVITY LAB.** Physicists have put Einstein to the test for more than a century, and yet general relativity's gravity waves remain unconfirmed. LIGO hopes to change that beginning this fall. LIGO LABORATORY

## LIGO ramps up search for gravitational waves

The hunt for major cosmic game is on. And while scientists have spent a century seeking the gravitational waves that Albert Einstein first predicted as a consequence of his general theory of relativity, this time could be different. In May, the Laser Interferometer Gravitational-wave Observatories (LIGO) finished a seven-year upgrade that increases its sensitivity tenfold. Astronomers expect these ripples in the fabric of space-time are created during violent events like supernova explosions and colliding black holes. Their hope is to one day use gravitational waves to unravel new details of the cosmos' most violent events. First they have to find them. — **E. B.**

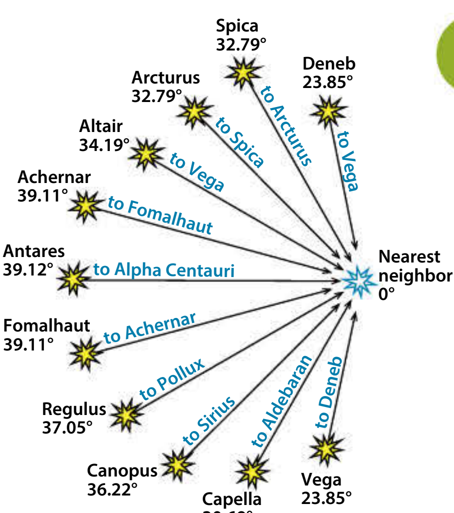
# Scientists uncover globular cluster surprises



**CLUSTER FORMATION FIRST.** Using ALMA, scientists studied various molecular clouds in the Antennae galaxies and found one incredibly massive and dense example (bottom image) that likely will become a globular cluster. HUBBLE (NASA/ESA)/B. WHITMORE (STScI); K. JOHNSON (UVA); ALMA (NRAO/ESO/NAOJ)

Globular cluster science got even more exciting — and strange — this spring as scientists revealed in *The Astrophysical Journal* the discovery of a possible precursor to such a conglomeration of stars as well as a few outliers from what we thought we understood about these objects. Most globular clusters observed today, including the 150 known in the Milky Way, formed some 12 billion years ago, so newborn finds are rare and the environments that would create such dense stellar clusters have never been seen — until now. Using the Atacama Large Millimeter/submillimeter Array (ALMA), scientists have discovered a star-free cloud containing 50 million times the mass of the Sun in molecular gas in the merging Antennae galaxies. They believe this environment is sufficiently dense to survive the forces that will try to pull the developing cluster apart. "We may be witnessing one of the most ancient and extreme modes of star formation in the universe," says Kelsey Johnson of the University of Virginia in Charlottesville and lead author of the June 10 paper on the protocluster.

Meanwhile, scientists using the Very Large Telescope to survey 125 globular clusters in the giant galaxy Centaurus A found a group of outliers that don't fit the brightness-to-mass ratio typical of these objects. These "dark" globular clusters contain far more mass than their brightnesses indicated they should. The team, led by Matt Taylor, a Ph.D. student at the Pontifical Catholic University of Chile in Santiago, mentions various possibilities for the extra mass in their May 20 paper, including intermediate black holes and dark matter, but they conclude that right now these objects are a mystery that will require further study. — **K. F.**




**FAST FACT** Among the sky's bright stars, Alpha and Beta Crucis are the closest companions; just 4.24° separate these neighbors in the Southern Cross.

## WON'T YOU BE MY NEIGHBOR?

**ISOLATION CHAMBER.** The magnitude 1.16 star Fomalhaut often goes by the moniker "The Solitary One" because no other bright star lies in its vicinity. But is this denizen of Piscis Austrinus the most isolated of the sky's luminaries? Not quite. A look at the closest neighbors for all of the night sky's brightest suns (those above magnitude 1.5) shows Antares to be the loneliest, separated from Alpha Centauri by 39.12°. Fomalhaut and Achernar are a mere 0.01° closer together. Increasing the magnitude threshold to 2.5 doesn't help, either; Fomalhaut then falls to sixth place, with Altair rising to the top spot.

*ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

# OBSERVING**BASICS**

BY GLENN CHAPLE

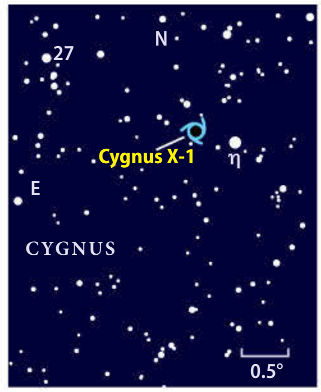
# Hidden "wow" factors

Sometimes the wonders of the universe come more from understanding what you're looking at.

Visual "wow" objects — those telescopic showpieces that awe and amaze even the most uninitiated observer — are rare indeed. You can expect guests at a public star party to gasp at the sight of lunar craters, Saturn's rings, or a splashy star cluster. Unfortunately, the vast majority of cosmic bodies show up in the eyepiece as either tiny specks (stars, including novae and supernovae; asteroids; quasars) or faint fuzzies (galaxies, nebulae, unresolved star clusters). Turn your telescope toward the Andromeda Galaxy (M31), one of the 10 wonders of the night sky, and a novice viewer might wonder if their breath fogged up the eyepiece.

To be wowed at the sight of a mere stellar speck or fuzzy patch, we need to understand its true nature. The awareness that the hazy oval blob in Andromeda is the combined light from hundreds of billions of unresolved stars in an enormous galaxy 15 million trillion miles away (a much more jaw-dropping figure than the standard 2.5 million light-years) evokes an intellectual "wow!"

This month, we'll take a telescopic voyage to HDE 226868. The name is impressive, but does it pack a visual or an intellectual "wow!"? To find out, go outside and train your telescope on the 4th-magnitude star Eta (η) Cygni. The StarDome map at the center of the magazine shows its location about midway between Beta (β) and Gamma (γ) Cygni. Scanning the area around Eta with a low-power eyepiece, you'll notice a pair of faint stars less than 0.5° to its east-northeast.




The relatively nearby black hole Cygnus X-1 has a 9th-magnitude blue supergiant companion that shines brightly enough to show up through backyard telescopes. *ASTRONOMY*: ROEN KELLY

If you're unsure where east is in the eyepiece field, just center Eta in the field, turn off the drive if the scope has one, and wait. The stars will follow Eta across the field. The brighter member of the pair is HDE 226868 (entry 226868 in the Henry Draper Extended star catalog produced by Harvard College in the late 1920s and early 1930s). A 9th-magnitude star, it's definitely *not* a visual "wow." But HDE 226868 has an invisible companion, and that's where the "wow" comes in.

Our story begins in 1964 when a pair of Aerobee rockets launched from White Sands Missile Range in New Mexico detected a powerful X-ray source in Cygnus, which was eventually pinpointed to HDE 226868. Scientists already had identified this star as a blue supergiant with a mass some 20 times that of the Sun. Even a cosmic beast of these proportions couldn't release the quantity of X-rays detected. Besides, the nature of the X-rays indicated a source that was exceptionally small. Where were they coming from?

In 1971, observations showed that HDE 226868 has a close companion with a mass about 15 times that of the Sun. The source had been found! What could be incredibly massive, incredibly small, and give off a boatload of X-rays? A black hole!

HDE 226868 and its invisible companion are what astronomers call an X-ray binary. The system's official designation is Cygnus X-1 (the brightest source of X-rays found in Cygnus). While the traditional stellar-mass black hole is the product of a supernova explosion/implosion, the Cygnus X-1 black hole seems to have formed when the progenitor star suddenly collapsed during its early stages of formation. Some 5 million years later, material from the supergiant continues to be gravitationally drawn to the black hole. These gases spiral inward, forming a whirlpool called an accretion disk. The closer the gases get to the black hole, the more rapidly they spin. Near the event horizon (the outer edge of the black hole), they whirl around at 60 percent the speed of light! Temperatures here reach many millions of degrees, and massive quantities of X-ray radiation are released.

Now that you know that HDE 226868/Cygnus X-1 is far more than an insignificant dot, take another look — this time with your mind. Picture a gigantic blue-white star locked in the gravitational embrace of a black hole, material from its surface being stripped away and dragged into a swirling maelstrom and ultimate oblivion. Cygnus X-1 is a cerebral "wow" if there ever was one!

The next time you look into the eyepiece and see a stellar speck in the middle of the field, pause to imagine what you're looking at. It might be an X-ray binary like Cygnus X-1 or a distant supergiant star in its death throes, soon to explode as a nova or supernova. Then again, it could be a star similar to the Sun — a mere dot until you realize that it may harbor a system of planets, one of which may be teeming with life. In the night sky, *everything* is a "wow" object.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: When is bright not so bright? Clear skies!

## FROM OUR INBOX

### Nothing strange about this

I have enjoyed *Astronomy* magazine for quite some time. The first article that I look for and read is Bob Berman's "Strange Universe." I was pleasantly surprised and enjoyed Bob's story "The nature of empty space" in the June 2015 issue (p. 30). Thanks, Bob. And thank you *Astronomy* for giving Berman some "space" about space. — **John Gardner,** Newnan, Georgia

### Composer, too!

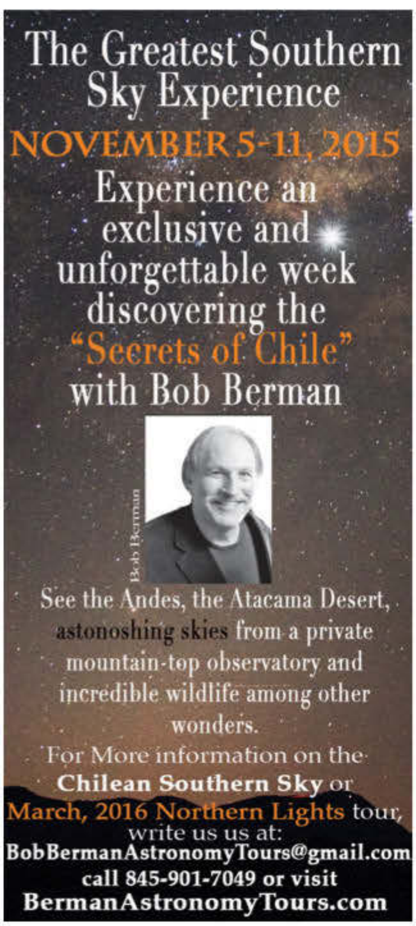
This is just a footnote to Ralph Wilkins fine article on the Herschel Museum in the May 2015 issue (p. 62). While it is widely appreciated that in addition to his many other talents, Herschel was a gifted musician, it's less well known that he was also a very accomplished composer. He wrote no fewer than 24 symphonies, a dozen concertos, several sonatas, and other works. While not as popular or complex as those of his contemporaries, including Mozart and Hayden, his symphonies are nonetheless melodious and original. — **Klaus Brasch,** Flagstaff, Arizona

BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**


ASTRO-PHYSICS
Dedicated to Craftsmanship!
Portability & Capacity
Absolute Encoder Option
New!!!
1100GTO
www.astro-physics.com
Machesney Park, IL USA
Ph: 815-282-1513
Astronomy magazine
2015 Star Products


ADM
ACCESSORIES
716-830-0413
Anthony Davoli
sales@admaccessories.com
www.admaccessories.com


Shelyak
INSTRUMENTS
Alpy
modular
spectroscope
www.SHELYAK.com


The Greatest Southern Sky Experience
NOVEMBER 5-11, 2015
Experience an exclusive and unforgettable week discovering the "Secrets of Chile" with Bob Berman
See the Andes, the Atacama Desert, astonoshing skies from a private mountain-top observatory and incredible wildlife among other wonders.
For More information on the Chilean Southern Sky or March, 2016 Northern Lights tour, write us us at:
BobBermanAstronomyTours@gmail.com
call 845-901-7049 or visit
BermanAstronomyTours.com


JMI Telescopes
JMI MOTOFOCUS
The product that put JMI on the map ends the focusing wiggles with the most compact drive system in the industry and fits over 200 telescope models.
Phone 303-233-5353
Web jmitelescopes.com
Email info@jmitelescopes.com
Facebook facebook.com/jmitelescopes


iOptron
For public outreach, travel, or the classroom... we have an AltAz mount for you.
#8100
MiniTower Pro
AltAz easy set up
33lb main payload
10lb payload 2nd scope
Ideal for public outreach
2-inch tripod
Now $1148
#8200
CubePro
AltAz easy set up
For lite scopes
Excellent Tracking
Ideal for travel, solar, or night-time
Now $428
#8507
Solar 60
60mm refractor
White glass solar filter
Ideal for classroom, or public outreach
Now $329
Solar 60 Includes FREE
Universal Smartphone Eyepiece Adaptor
Astronomics
1.800.422.7876
www.astronomics.com
B&H Photo
1.800.606.6969
www.bhphotovideo.com
High Point Scientific
1.800.266.9590
www.highpointscientific.com
OPT
1.800.483.6287
www.opttelescopes.com
Woodland Hills Telescopes
1.888.427.8766
www.telescopes.net
Ontario Telescope (Canada)
1.905.487.6363
www.ontariotelescope.com
www.iOptron.com
Innovation • Value • Customer Support

# Starmus will honor Stephen Hawking in 2016

Next summer, the science festival will revolve around the life of the renowned theoretical physicist.

Stephen Hawking speaks at the 2014 Starmus Festival in Tenerife, Canary Islands, Spain. MAX ALEXANDER/STARMUS FESTIVAL

At a press conference in April, a distinguished group announced that next year's Starmus Festival will honor the life and times of theoretical physicist Stephen Hawking. The event will gather the greatest minds in astronomy and related sciences, music, and the arts for a memorable weeklong celebration. The theme will be "Beyond the Horizon: Tribute to Stephen Hawking." *Astronomy* magazine will proudly again be the primary media partner for Starmus.

Starmus founder and director Garik Israelian, astrophysicist and Queen guitarist Brian May, and Stephen Hawking revealed the theme and date at the Royal Astronomical Society in London. The third Starmus Festival will take place June 27–July 2, 2016, in Tenerife, Canary Islands, Spain, the same location as the first two events.

Among the big-name speakers at Starmus III, in addition to Hawking, Israelian, and May, will be 10 Nobel Prize winners, including chemists Harry Kroto and Eric Betzig; physicists Robert Wilson, Adam Riess, and Brian Schmidt; and biologists Carol Greider and Elizabeth Blackburn. Also speaking will be astronauts including American Rusty Schweickart and Canadian Chris Hadfield, as well as astronomers Kip Thorne, Lord Martin Rees, Neil deGrasse Tyson, and Neil Turok.

The festival will again include a Sonic Universe Concert featuring legendary rock stars who also are interested and involved with science. In addition to May, Starmus participants and board members have included the great keyboardist Rick Wakeman, famous for his solo work and for his time in the group Yes, and Peter Gabriel, celebrated for his work with Genesis and his long solo career.

Starmus III will take place mostly in Tenerife but also on La Palma, at the world's largest optical telescope, the 10.4-meter Gran Telescopio Canarias. It also will feature a Mount Teide star party under some of the greatest, darkest skies on Earth that, as with the second festival, will have its own soundtrack performed by the progressive rock band Nosound.

Garik Israelian, the founder and director of the Starmus Festival, is an astronomer at the Institute for Astrophysics on Tenerife. MAX ALEXANDER/STARMUS

More speakers will be announced as plans develop. Starmus also will feature an astrophotography contest and an astrophoto school.

For more information on the 2016 Starmus Festival, see www.starmus.com.

*Astronomy* magazine and our website, Astronomy.com, will carry updated information frequently as plans develop.

The Starmus Festival takes place on the beautiful Canary Islands under one of the darkest skies on Earth. DAVID J. EICHER



Brian May jams on his famous Red Special during the 2014 Starmus Festival Sonic Universe Concert. DAVID J. EICHER

**David J. Eicher** *is editor of* Astronomy *magazine and a board member of the Starmus Festival.*


JOIN ASTRONOMY MAGAZINE'S
AURORA ADVENTURE
OCTOBER 5–15, 2015
Experience a once-in-a-lifetime northern lights tour along the Norwegian coast and interior with Astronomy magazine and TravelQuest International. The trip includes:
6 nights of dark-sky aurora viewing
4 days cruising Norway's fjords aboard the MS Nordnorge
3 days exploring past and present Sami culture
Lectures and night sky viewing with Astronomy staff
Guided tours by local experts
And much more!
Astronomy magazine
TRAVELQUEST international
RESERVE YOUR SPOT TODAY!
Visit www.astronomy.com/norway
P23642


TAKE THE UNIVERSE with you
ASTRONOMY'S DIGITAL EDITION lets you:
* Link to website content, blogs, advertisers' websites, audio, and video.
* Zoom in and magnify to see all the details of Astronomy's stunning images.
* Take your issues with you wherever you go — and save on storage space!
ASTRONOMY.COM/DIGITALEDITIONS
SPECIAL 500th ISSUE!
Astronomy
500 COOLEST THINGS ABOUT SPACE
Powered by Zinio™, digital editions are available on PC; Macintosh; Android™; iPad®; iPhone®; and Windows 8.
Zinio is a registered trademark of Zinio, LLC. Android is a trademark of Google Inc. iPad and iPhone are trademarks of Apple Inc., registered in the United States and other countries. Windows is a registered trademark of Microsoft Corporation in the United States and other countries.
P26036

# WEBTALK

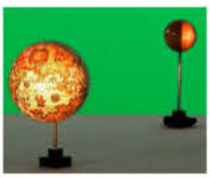
What's new at Astronomy.com.
**BY KARRI FERRON**

**REGISTER TODAY!** Go to www.Astronomy.com/register for access to bonus articles, photos, videos, and more.

## Featured video

### "How to observe a lunar eclipse"

The biggest celestial event of the fall will bring out all kinds of weird phrases in the news, including "Super Moon" and "Blood Moon." What's with the unscientific names? For many newscasters, it's a fun way of saying that on September 27, the closest Full Moon of 2015 will pass through Earth's dark inner shadow in a stunning total lunar eclipse (see p. 56). Observers in North and South America, Europe, and Africa all have front-row seats to the event, and to help you prepare, check out Senior Editor Michael E. Bakich's video "How to observe a lunar eclipse." He starts with a detailed introduction and demonstration that show what happens during a lunar eclipse — and why one doesn't occur every month, even though a Full Moon does. Then, he explains what terminology you'll need to know and the differences between these events and their counterparts, total solar eclipses. And finally, Bakich explores why it's easy to observe and photograph lunar eclipses and what to look for as you're watching these special events. So check out the video before September 27 at **www.Astronomy.com/lunareclipse**, and enjoy this eclipse of the "Super Moon."



#### OBSERVING TOOLS

### Weekly observing podcasts

Each week, Senior Editor Michael E. Bakich records a podcast featuring three deep-sky objects you can see in the next seven days. He adds variety by selecting targets for various optics: some for binoculars, some for small telescopes, and others for larger instruments, like an 8-inch scope. He even shares bonus objects, whether multiple double stars, a pair of star clusters, or a group of galaxies. No matter what his targets, though, Bakich always provides detailed observing information and fun facts about each choice. Get the inside scoop at **www.Astronomy.com/podcast**.

#### COMMUNITY

### Reader Photo Gallery

Browse thousands of beautiful images like this one of the Milky Way over the 2015 Texas Star Party by Jon Talbot, and submit your own. Explore our numerous gallery catalogs, including Galaxies, Nebulae, Stars and Star Clusters, Planets, the Sun and Moon, Comets, and Cosmic Creations. Comment on photos and learn from others' techniques. Beginners and advanced amateurs anywhere in the world are welcome at **www.Astronomy.com/readergallery**.

**FOLLOW *ASTRONOMY***

www.twitter.com/AstronomyMag

www.facebook.com/AstronomyMagazine

plus.google.com/+astronomymagazine

# Multiverses SCIENCE OR SCIENCE FICTION?

## **Bob Berman** explores the strange ideas that drive theorists to believe in parallel universes.

Tighten your seat belt. This odyssey takes us beyond our universe to a realm of parallel dimensions. We will not just explore today's popular multiverses — theories that suggest ours is one marble in an infinite bag; we'll see why some physicists regard them as a threat to science.

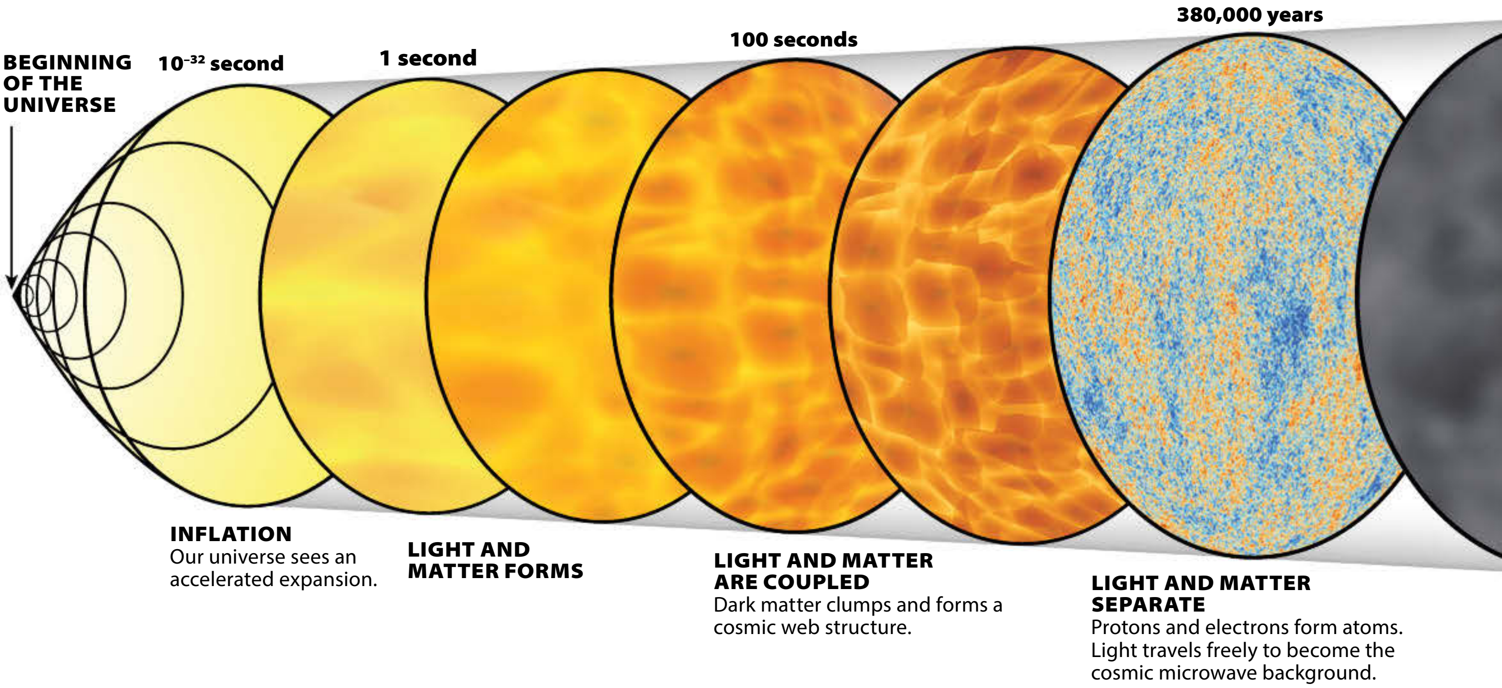
Few scientists would dispute that there's lots of stuff over the cosmic horizon, beyond what we can ever see. Light from the farthest visible objects traveled for more than 13 billion years, from galaxies currently located some 40 billion light-years away. There's no reason for galaxies to simply stop existing at this visible boundary. Moreover, the strong evidence that space is flat on large scales means that the vast bulk of the universe must lie over the horizon, beyond where objects recede at light-speed. In fact, many cosmologists think the overarching universe may be infinite in size and thus infinite in its inventory of galaxies. (We will return to this "infinite" business a bit later.)

Since we'll be forever blind to and ignorant of objects whose light can never reach Earth, we could call all that stuff a separate universe. Logically, it has the same physical laws as ours. This is the most straightforward type of multiverse. As renowned Massachusetts Institute of Technology physicist Max Tegmark notes, "If you define our universe as everything we can observe, then I'd bet good money on there being parallel universes."

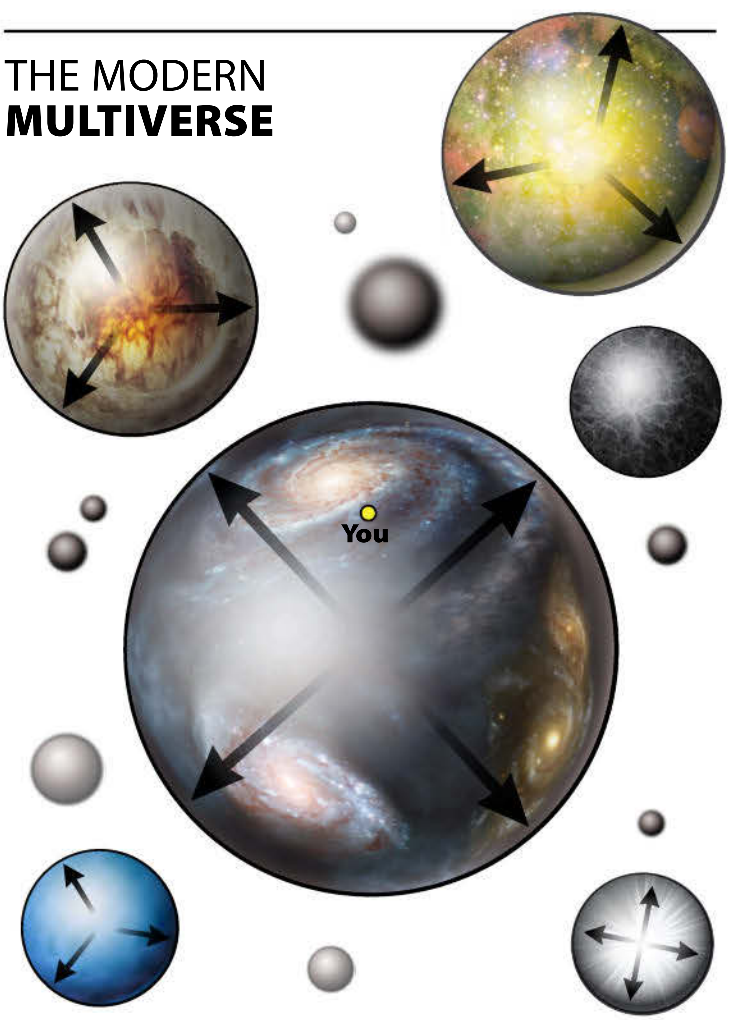
**Bob Berman** *is* Astronomy*'s Strange Universe columnist. His latest book is* ZOOM: How Everything Moves *(Little, Brown and Co., 2014).*

ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY; *ASTRONOMY*: WILLIAM ZUBACK (CHILD)

# OUR COSMIC HISTORY




THE MODERN **MULTIVERSE**




After we accept the frustration of never knowing anything about those gazillion galaxies, stars, and planets, nothing's particularly weird about the situation. Some simply label that vast realm the "rest-o-universe." It's simple: There's them and us. Almost all astronomers are on board that ship.

## The modern multiverse

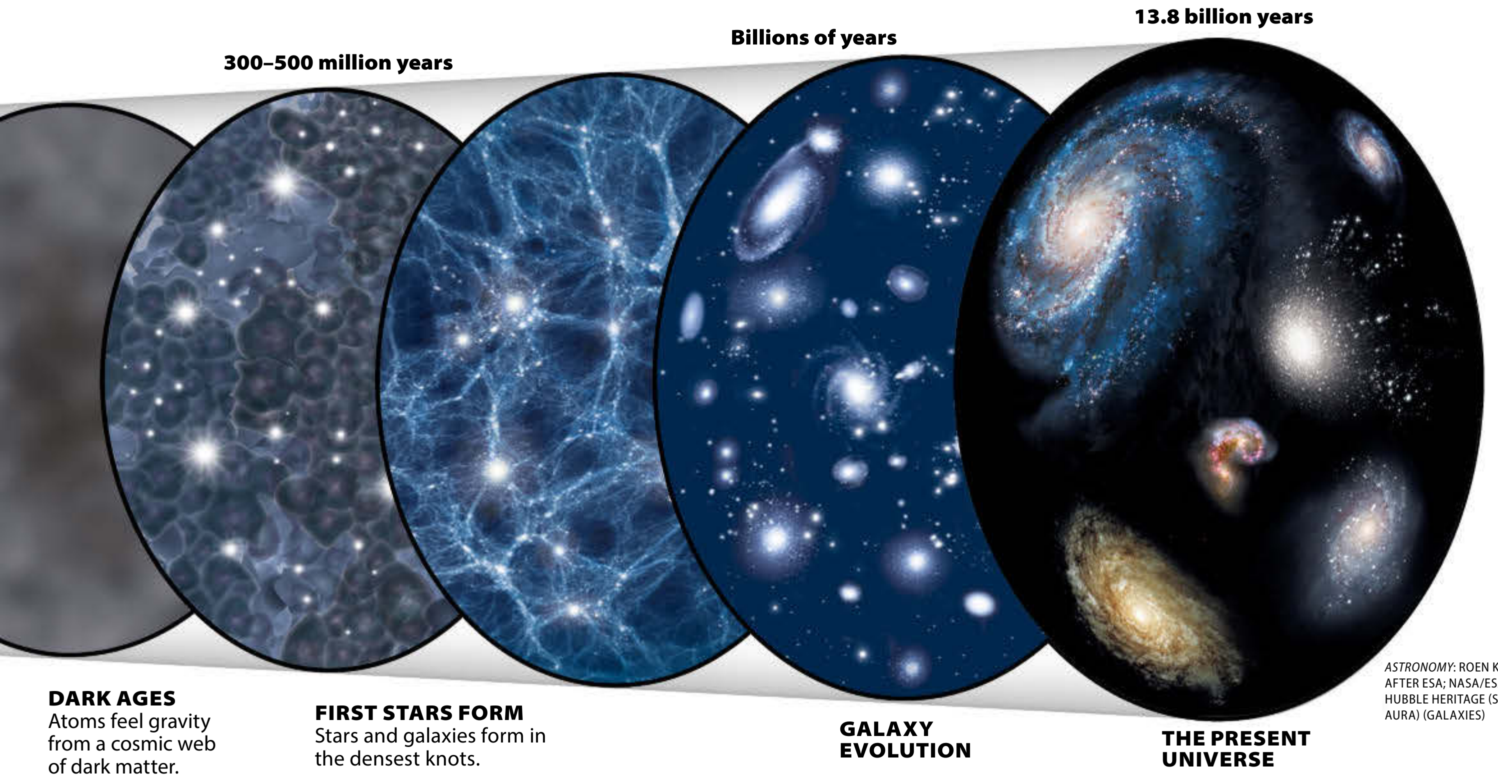
Things get controversial and downright bizarre when we examine the main multiverse hypotheses, the ones that have intrigued the public for over a decade. Their champions are well-known theorists and science popularizers like Stephen Hawking, Michio Kaku, Brian Greene, and Tegmark.

MIT's Alan Guth created the original inflation theory in 1979 to describe our universe's rapid expansion in its first few fractions of an instant. He supports a revised version originated by Stanford theorist Andrei Linde called chaotic inflation.

This says that as the cosmos wildly and forever increases in size, various inflating parts of space form. Each belongs to the same universe but grows so large that inhabitants will never know what happens in any other parts of the universe. "In some of these parts, laws of physics may be realized in different ways," says Linde. "Thus, one may say that our universe in effect becomes a multiverse, a huge eternally growing fractal consisting of many different 'universes' with different properties."

No one can ever traverse the space between these bubbles, one of which is our cosmos. Thus we have an infinitude of separate universes.

Guth and Linde shared the $1 million 2014 Kavli Prize in Astrophysics with fellow founder Alexei Starobinsky for their inflation work. They even met President Obama.




*ASTRONOMY*: ROEN KELLY, AFTER ESA; NASA/ESA/HUBBLE HERITAGE (STScI/AURA) (GALAXIES)

## String discord

A different multiverse involves string theory. Originally, theorists postulated tiny strings along with many hypothesized extra dimensions as a hopeful way to explain the four fundamental forces — gravity, electromagnetism, and the strong and weak interactions — and the standard model of particle physics.

It has not succeeded. Beyond the utter lack of evidence for extra dimensions, it does not predict our universe, nor can it explain the accelerating expansion of the cosmos discovered in 1998. So it's increasingly viewed as a failed theory. But it does "predict" $10^{500}$ different ways reality can materialize. This itself is vague to the point of uselessness.

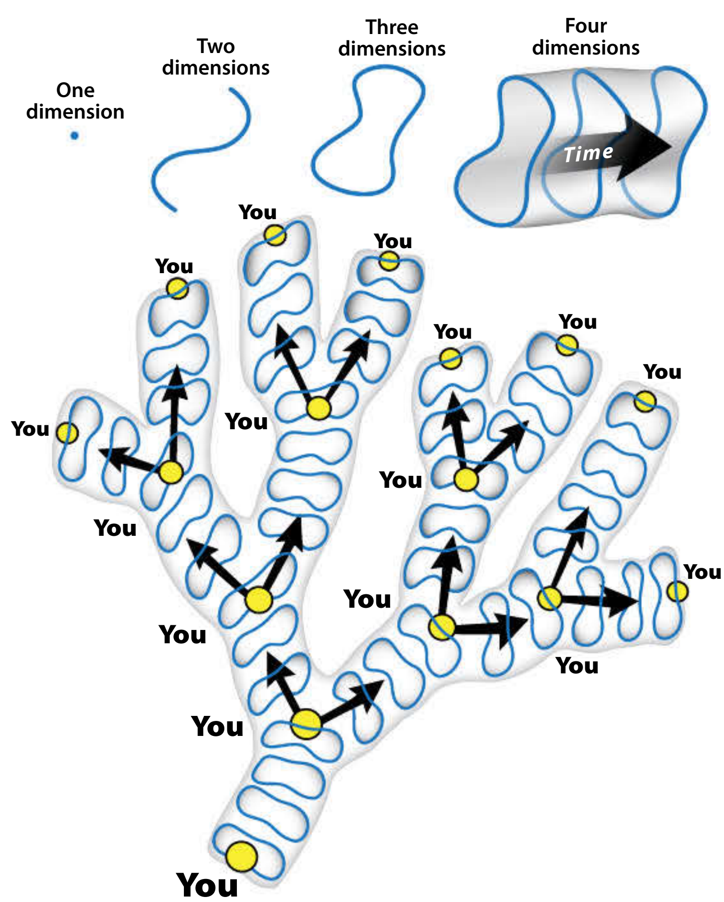
A very different multiverse is based on quantum theory's many worlds interpretation (MWI).

We've known for over 80 years that the act of observation can alter experimental results. But why? Moreover, why does an electron, when it comes to a fork in the road, go one way and not the other?

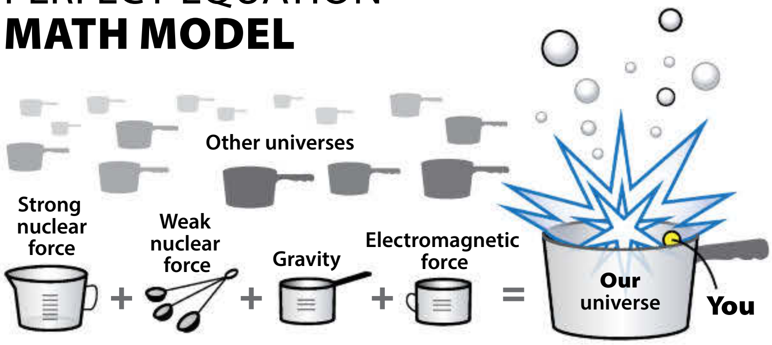
The MWI, a mainstream if minority interpretation of reality, claims that every choice in nature creates a separate universe that then breaks off from the others and continues on. If you turn left at an intersection instead of turning right, another "you" materializes who does indeed turn right. An entire new universe continues with that reality permanently enshrined. You are never aware of any other universe but the one you know, and the same is true of all the other yous that made other choices.

Separate universes even sprout up when a leaf falls here and not there, a few inches away. Many worlds' multiverses thus keep increasing their numbers wildly.

## STRING THEORY AND THE MANY WORLDS INTERPRETATION



## PERFECT EQUATION **MATH MODEL**




### Math makes it real

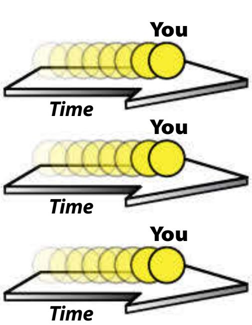
Then you have the mathematical universe hypothesis, also called the ultimate ensemble. This multiverse contains everything that is mathematically possible. It's championed by those, like Tegmark, who think mathematics is the basic reality of the cosmos as opposed to being a human conceptual tool. This view says that everything that can happen mathematically does happen in its own separate universe.

The anthropic principle provides more multiverse rationales. This is the theory that while our universe is simple in many ways, it contains dozens of physical constants whose values are Goldilocks-perfect for life to exist. If the fine-structure constant that governs the strength of the electromagnetic force was barely different, or the power of the strong force or the strength of gravity were slightly tweaked, there could be no atoms, no stars, and no chance for life. Ours is a universe so precisely fine-tuned for life, science must ask why.

By arguing for the existence of countless other random universes, the vast majority of which would not have the physical properties that permit life, multiverse advocates can say, "See? Taken as an aggregate, nothing special is going on. The multiverse landscape contains every sort of universe, and we just happen to live within one of those that supports life." It is a way to make our exceptional-seeming cosmos less extraordinary.

A few other multiverse candidates exist, but you get the idea. The whole thing is exciting because it unveils breathtaking new possibilities that paint the overall universe to be even vaster than we'd assumed.

## **INFINITY** MODEL




### The infinite yous

Speaking of "vast," let's go back to that infinity business, which figures prominently in multiverse models. If true, there's definitely another "you" out there on another Earth in a nearly identical universe to ours. After all, infinity means no limits. Guth maintains that a multiverse leads to the conclusion that "anything that can happen will happen — and it will happen an infinite number of times."

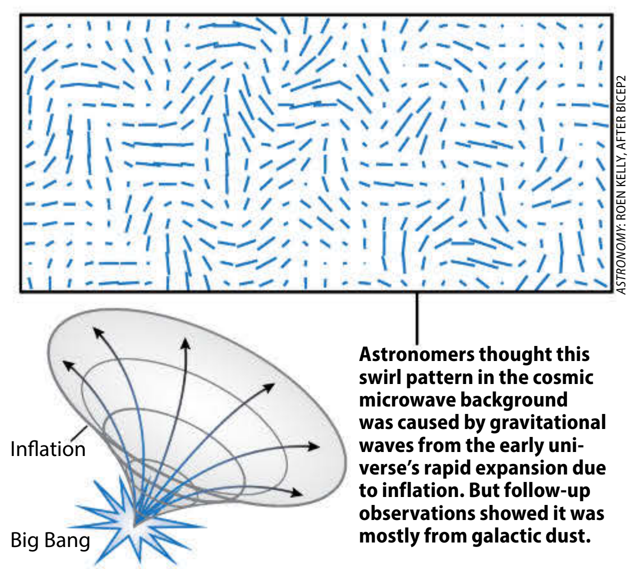
So another "you" exists who wore the same socks to the prom with the little hole in one. This other you even has your cat, with identical markings. Infinity means there wouldn't be just one exact copy of you with matching dental fillings. No, there are infinite duplicate yous. There also must be an endless army of yous with one opposite personality trait. None of them would ever leave a dirty glass in the sink.

Doesn't smell right? Happily, there's been a recent anti-infinity trend among physicists. Last year, a prominent pair of theorists, mathematician George Ellis and physicist Joseph Silk, wrote an editorial in the journal *Nature* encouraging cosmologists to heed the warnings of mathematician David Hilbert, who died in 1943. "Although infinity is needed in mathematics, it occurs nowhere in the physical universe," the pair opined.

In any case, internal mathematical consistency is not enough to adequately support a multiverse theory, whether it involves strings, inflation, or hypothesized higher-dimensional colliding membranes that could smack our universe into another. That's because math can diverge from physical reality, as Zeno showed in 450 B.C. with his famous Achilles and the tortoise thought experiment.

But multiverse hypotheses generate deep objections that go beyond their underlying math. Critics say they are nonfalsifiable and thus indistinguishable from philosophy and no more useful than saying, "God did it." Last December, Ellis and Silk wrote, "The imprimatur of science should be awarded only to a theory that is testable."

## **INFLATION** THEORY




**Astronomers thought this swirl pattern in the cosmic microwave background was caused by gravitational waves from the early universe's rapid expansion due to inflation. But follow-up observations showed it was mostly from galactic dust.**

*ASTRONOMY: ROEN KELLY, AFTER BICEP2*

Going further, last year, writing in *Edge*, Paul Steinhardt, Princeton University's Albert Einstein Professor in Science and an early inflation advocate, wrote, "The notion that we live in a multiverse in which the laws of physics and the properties of the cosmos vary randomly from one patch of space to another [should be retired]."

Strong words. Well, should we really ax the whole multiverse business? A big problem many critics cite is that multiverse models don't predict anything, and thus they allow everything. Moreover, Steinhardt is convinced multiverse theories are put forward mainly to try to salvage failed hypotheses like string theory.

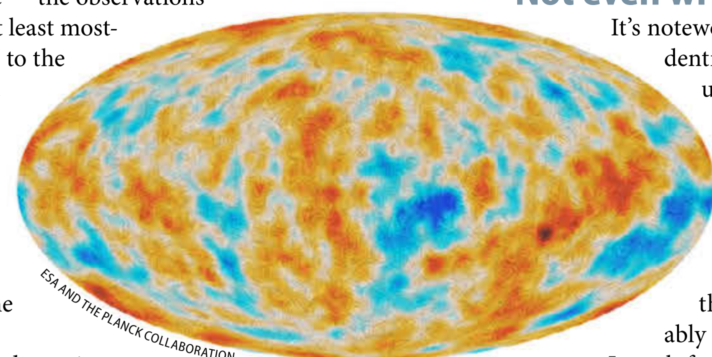
"Science is useful insofar as it explains and predicts why things are the way they are and not some other way," he wrote. "… A Theory of Anything is useless because it does not rule out any possibility and worthless because it submits to no do-or-die tests."

Still, "parallel universes" are such a sci-fi staple, they're more familiar to the public than most other aspects of theoretical physics and astronomy. TV science specials remain in love with the multiverse idea and usually let its champions make on-screen claims of putative evidence.

In 2014, the most convincing ever astrophysical support emerged for the multiverse and made front pages around the world.

## Evidence clouded

It was a South Pole experiment called BICEP2. Yet dramatically and amazingly, within a few short months, the find was discredited. Turned out, it wasn't the experiment but the interpretation that proved faulty. Globally headlined as the first-ever verification of gravity waves that are the supposed signature of inflation — the wild expansion of the newborn universe — the observations are now thought to be at least mostly, if not completely, due to the existence of cosmic dust particles in our Milky Way Galaxy.



ESA AND THE PLANCK COLLABORATION

Before the BICEP2 results were discredited, they were cited by some multiverse cheerleaders as support for the chaotic inflation model, which was in turn offered as evidence for parallel universes. Critics howled at what they characterized as chains of unwarranted assumptions. Some continue to ask why the multiverse idea always seems exempt from science's normally strict standards and is allowed to tiptoe along the shorelines of mere conjecture.

Actually, as long as speculative cosmological models are allowed into the party, it's also possible that reality lies in the opposite direction from the multiverse. We're talking about the notion that even our own cosmos is simple rather than multifarious.

Ancient Greek thinkers like Parmenides and Zeno were among the first to argue that the cosmos (or "Being") is a single undifferentiated entity. By this account, there are no separate events happening around us. Rather, the cosmos is a single event. This view of fundamental oneness, which has some modern quantum support, has appeared in nearly all cultures through the centuries and is antithetical to multiverses.

The bottom line seems to be that while "multiverse" is mind-stretching and certainly possible, it may be pointless and even counterproductive as an explanation for our visible universe's properties. Meanwhile, debate rages over whether any observation could ever disprove multiverse models — which pushes them outside the realm of science.

In a *Newsweek* cover story in 2012, Columbia University cosmologist Brian Greene wrote: "Evidence for the multiverse might come from potential collisions between our expanding universe and its neighbors. Such a cosmic fender bender would generate an additional pattern of temperature variations in the microwave background radiation [the remnant radiation of the Big Bang] that sophisticated telescopes might one day detect. Many consider this the most promising possibility for finding evidence in support of the multiverse. That there are ways, long shots to be sure, to test the multiverse proposal reflects its origin in careful mathematical analysis. Nevertheless, because the proposal is unquestionably tentative, we must approach it with healthy skepticism and invoke its explanatory framework judiciously."

Tegmark agrees: "Parallel universes are not a theory, but [they're] predictions of certain theories which are arguably testable, for example cosmological inflation. This is why they're discussed not only in science fiction, but increasingly also at science conferences."

## Not even wrong?

It's noteworthy that highly credentialed individuals still use equivocal language as they describe even the most plausible multiverse models out there. Evidence might one day be detected for certain theories which are "arguably testable?"

Is such fuzziness good enough to qualify as science?

Given the current multiverse infatuation, it may be fairest to give the last word to a prominent skeptic. Columbia University mathematical physicist Peter Woit, who maintains the popular multiverse-critical blog Not Even Wrong, pulls no punches.

"Physicists had huge success in coming up with powerful compelling fundamental theories during the 20th century," he explains, "but the last 40 years or so have been difficult, with little progress. Unfortunately, some prominent theorists have now basically given up and decided to take an easy way out. The multiverse is invoked as an all-purpose, untestable excuse. They allow theoretical ideas like string theory that have turned out to be empty and consistent with anything to be kept alive instead of abandoned. It's a depressing possibility that this is where physics ends up. But I still hope this is a fad that will soon die out. Finding a better, deeper understanding of the laws of physics is incredibly challenging, but it's within our capability as humans, as long as the effort is not overwhelmed by those selling a non-answer to the problem."

Whoa, intense. We've got to toss the multiverse if we care about physics!

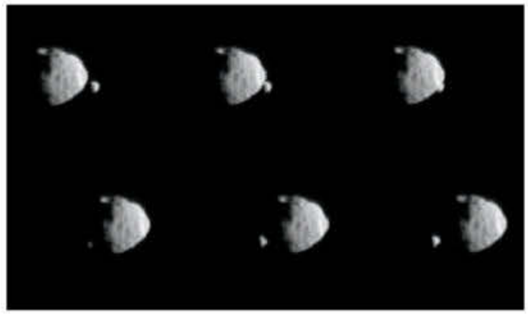
Of course, if an infinite multiverse does exist, some other Woit is out there saying the exact opposite.

WHAT HAPPENS IF STRING THEORY IS WRONG? FIND OUT AT **www.Astronomy.com/toc.**

# MOON MUSINGS

## Q: ON THE MARTIAN SURFACE, WOULD THE MOONS DEIMOS AND PHOBOS BE VISIBLE TO THE UNAIDED EYE?

***David De Roo,** Silver Spring, Maryland*



**NASA's Curiosity rover watched Phobos, Mars' largest moon, occult the diminutive Deimos in 2013 using the long lens of its Mastcam.** NASA/JPL-CALTECH/MSSS/TEXAS A&M UNIV.

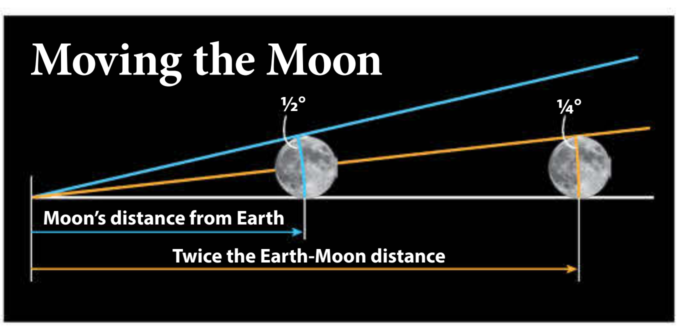
**Astronomers suspect the odd ridge on Saturn's moon Iapetus that makes it look like a walnut might have been formed when a moon or set of rings crashed to the surface.** NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

**A:** Mars' moons are easily visible at night from the surface of the Red Planet. Phobos — the nearer, larger, and brighter of the two — would be obviously non-round. A sharp-eyed observer would be able to make out the moon's largest craters and see the jaggedness of its terminator — the dividing line between light and dark. Phobos rises in the west and sets in the east in the span of around four hours a couple times each martian day and is up at some time each night. It also noticeably changes phase between rising and setting. From the Curiosity rover's point of view, on some evenings Phobos rises out of the slowly fading blue-gray twilight in crescent phase, transits as a quarter moon, and sets as a gibbous moon. Near fall or spring equinox, it goes into eclipse before becoming full. Near the start or end of totality, Phobos would remain faintly visible. And on a few days each year, it also transits the Sun during the daytime in an annular or even a partial solar eclipse.

Deimos appears much smaller but is easily visible and brighter than any star in the martian sky at night. It is a little outside the areostationary orbit — it goes around Mars almost as fast as the planet spins. So it is visible for a couple nights, then gone for a few nights, and then back. During the night, the stars move past it, but it does rise in the east and set in the west. Eclipses involving Deimos are rare but do occur near the solstices.

During dust storms, the rising and setting of the moons would be lost in the murk, but they still would be visible when they are high in the sky at night. Out of dust storms, Phobos is sometimes visible in daylight, high in the early morning or late afternoon sky.

***Mark Lemmon***
*Texas A&M University*
*College Station*




**Degrees of sky are irrelevant to true distance between stars. If the Moon's distance from Earth doubled, its apparent size would shrink by half, even though its physical diameter would remain unchanged.** *ASTRONOMY:* ROEN KELLY

## Q: WHAT EXACTLY IS A DEGREE IN TERMS OF THE DISTANCE BETWEEN STARS?

***Stephanie Johnson***
*Maple Grove, Minnesota*

**A:** A measurement in degrees has nothing to do with the true distances between celestial objects. When we talk about apparent distances or sizes, however, degrees do come into play.

Here's an example: The Moon's true diameter is 2,159 miles (3,474 kilometers). But the width that we see of the Full Moon — its apparent diameter — is ½°. That's how much of an angle it subtends at its distance from us. To prove there's no connection between true and apparent diameter, let's imagine that we can double the Moon's distance from Earth. Its apparent size would shrink to ¼° from our vantage point, but its true diameter would remain unchanged.

***Michael E. Bakich***
*Senior Editor*

## Q: CAN A MOON HAVE ITS OWN MOON?

***Garvin McDaniels***
*Benton, Kansas*

**A:** Yes, it is possible for a moon to itself have moons and/or rings, and there are a few places where scientists have suggested that this is (or was) the case. However, moons tend to rotate slowly, and this makes it difficult for a moon's moon to find a stable orbit.

In 2008, some scientists claimed that an electromagnetic detector on board the Cassini spacecraft had found rings around Saturn's moon Rhea. This claim did not hold up when the larger community carefully checked it out, but some astronomers still believe that markings around Rhea's equator are the remnants of an ancient ring that fell onto the surface.

Iapetus, another moon of Saturn, is best known for its highly contrasting bright and dark hemispheres. But it has several other mysterious characteristics, including a bulging shape that indicates it once spun much faster than it does now as well as an equatorial mountain range. Some scientists have proposed a model involving an ancient moon around this moon, which might have produced both features as it spun inward toward Iapetus and then broke up into a ring.

It is actually impossible in most cases for a moon around a moon to be stable in the long term because nearly all moons rotate once per orbit so they always keep the same face toward their planet (Earth's Moon is the best-known example). Such a slow rotation rate means that any moon-orbiting object would orbit faster than the moon rotates, which would cause the moon-orbiting object

to spiral inward toward the moon (rings, by the way, are not affected by this process). Most planets, by contrast, rotate quickly, so their slow-orbiting moons gently and safely spiral outward (the exceptions, Mercury and Venus, have no moons, likely due to the same effect).

***Matthew Tiscareno***
*Cornell University*
*Ithaca, New York*

**Q: SIRIUS, OUR BRIGHTEST STAR, IS ORBITED BY A WHITE DWARF — A DEAD STAR'S CORE. WHERE IS THE PLANETARY NEBULA THAT WOULD HAVE FORMED WHEN IT SHED ITS SKIN?**

***Mark Socha***
*Saginaw, Minnesota*

**A:** The white dwarf Sirius B probably would have had a planetary nebula around it at one point, long ago. The planetary nebula phase of stellar evolution is a short-lived phenomenon, astronomically speaking, generally lasting only about 50,000 years. Sirius B is estimated to be over 100 million years old, so any planetary nebula it might have had is long gone.

After a low-mass star (lower than 8 solar masses or so) evolves past the hydrogen-burning main sequence phase of its lifetime, it goes through several other phases, such as the red giant phase and the asymptotic giant branch phase. Eventually, the outer layers are shed in a slow wind, and the hot core of the star is exposed. This hot central core, in the process of becoming a white dwarf, has temperatures of around 100,000 kelvins. This is hot enough to emit a lot of ultraviolet radiation, which ionizes the blown-off material, causing it to glow and become a planetary nebula.

There are two factors that cause this phase to be short-lived. One is simply that the material blown off the star continues to drift away and eventually dissipates into the interstellar medium. Additionally, as the central star cools and becomes a white dwarf, its luminosity drops to the point where it would be inefficient in ionizing the gas, even if it were present.

***Brian Williams***
*NASA Goddard Space Flight Center*
*Greenbelt, Maryland*

## Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

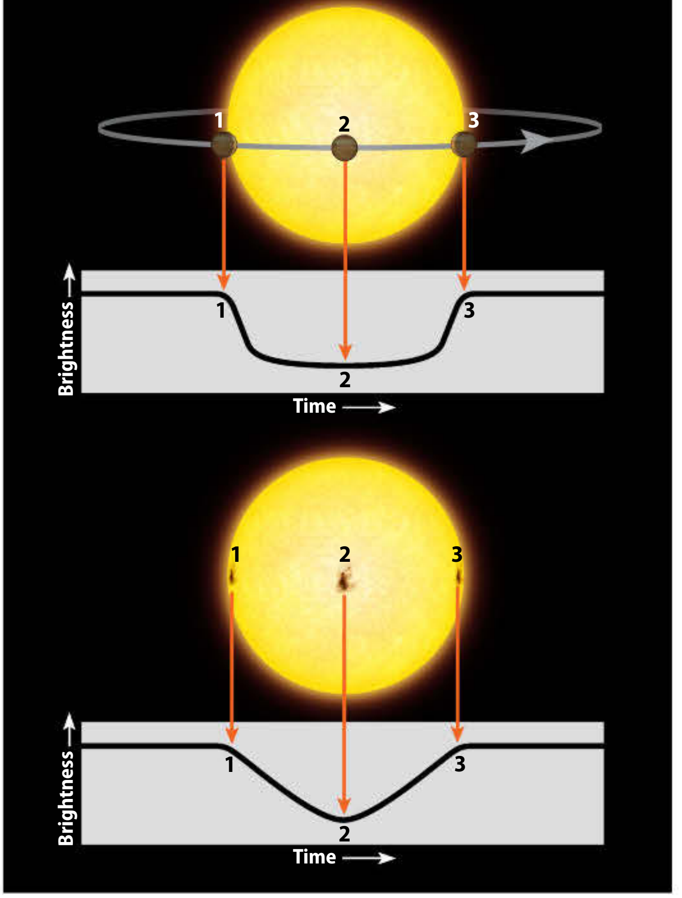
**Q: AT TENS, HUNDREDS, OR THOUSANDS OF LIGHT-YEARS FROM A STAR, HOW DO YOU DISTINGUISH BETWEEN EXOPLANETS, SUNSPOTS, AND DWARF BINARY COMPANIONS?**

***Bill Fox***
*Loganville, Georgia*

**A:** While the items you list all produce drops in starlight as they cross their stellar host, an exoplanet's signature is often well characterized.

Starspots can occupy the same area as an exoplanet (or larger or smaller) and dim starlight as they rotate in and out of view. However, a number of things distinguish them from a planet transit. Spots do not have sharp edges or circular shapes, but they do appear with each stellar rotation and have a period that can mimic a planet. Spots, however, move in both longitude and latitude as the star rotates, causing their period to change slightly after a few rotations. Stars with spots also tend to have larger amplitude variations in their light, which are usually greater than a planet transit depth and lead to a sine-like light curve.

## Spurious spots




**The light curve created by an exoplanet passing in front of its star (top) is different from the one caused by a starspot. These subtle inequalities tell astronomers which is which.** *ASTRONOMY*: ROEN KELLY

Stellar companions differ from exoplanet transits in a number of ways as well. Planets do not shine in the optical-light wavelengths, so they cross the star as black disks. Binary companions are self-luminous and cause not only a different shape of eclipse (V compared to a U shape) but also a color change in the light. This happens because they block some light and emit some as well, changing the total light color we see during their eclipse.

Exoplanet transits are usually U-shaped due to both their blackness and the host stars' limb darkening — where the center of the star is brighter than the edge. They also keep the same period in most cases (exceptions are exoplanets in highly elliptical orbits). We measure the planet's size by the depth of its transit, given that the star's radius is known.

Thus, while it is often the case that astronomers can distinguish a planet transit from starspots or eclipsing binary companions, it is not perfect. Smaller planets, more variable stars, and less than optimal light curve data can be confusing and fool us at times.

***Steve Howell***
*NASA Ames Research Center*
*Moffett Field, California*

**MARTIN RATCLIFFE** and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

# September 2015: Totality's long embrace

**The Full Moon slides through the southern part of Earth's dark umbral shadow the night of September 27/28, mimicking this eclipse from April 14/15, 2014.** RICHARD McCOY

The first half of 2015 featured lots of evening planets, but as autumn begins, the focus shifts to the predawn sky. Venus, Mars, and Jupiter return to prominence on September mornings. Although the evening sky quiets some, Mercury briefly pokes above the horizon and Saturn continues to look spectacular. Meanwhile, the overnight hours offer some of the year's best views of Uranus and Neptune.

But September's star attraction lies closer to home. The Moon takes center stage three times during its monthly tour of the sky. In the first act, Earth's satellite passes in front of 1st-magnitude Aldebaran before dawn September 5. Observers along a line that runs from the western shore of Lake Superior to Florida's east coast will see the star emerge from behind the Last Quarter Moon's dark limb as the pair rises. The farther north and east of this line you live, the higher the two objects will appear. From New York City, for example, they stand 11° above the eastern horizon when Aldebaran returns to view at 12:40 A.M. EDT.

The Moon passes in front of a much bigger and brighter star September 13. The target this time is the Sun, and Luna obscures part of it for people in southern Africa, southern Madagascar, and parts of the Indian Ocean and Antarctica. The best sites on land for this **partial solar eclipse** are around Cape Town, South Africa, where the event starts shortly before sunrise and peaks at 5h43m UT. The Moon then blocks 30 percent of the Sun's surface area.

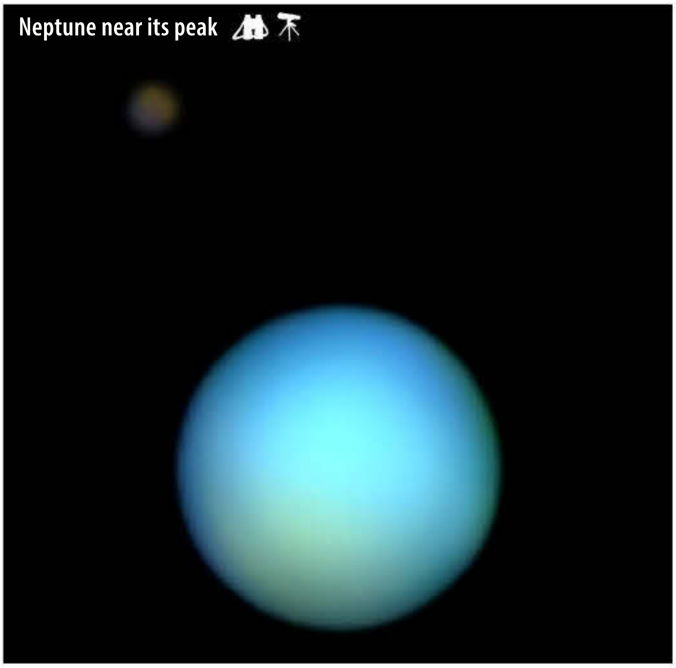
The Moon's final and most impressive act arrives the night of September 27/28 when it dives deep into Earth's shadow to create a spectacular **total lunar eclipse**. Observers across most of North America will see all 72 minutes of totality the evening of the 27th. Viewers in most of Europe, Africa, and the Middle East will witness the eclipse before dawn on the 28th. (See "Eclipse of the Super Moon" on p. 56 for complete details.)

In contrast to lunar events timed in minutes or hours, planets typically remain on display for weeks or months. Case in point: **Mercury**, which hangs low in the west after sunset during September's first half. The planet reaches greatest elongation September 4, when it lies 27° east of the Sun. Although that sounds pretty impressive, Mercury remains a horizon hugger for Northern Hemisphere observers. The ecliptic — the Sun's apparent path across the sky that the planets follow closely — makes a shallow angle to the western horizon after sunset around the autumnal equinox. Most of Mercury's elongation translates into distance along the horizon and not altitude above it.

From 40° north latitude, the inner planet stands just 3° high a half-hour after sunset on the 4th. Mercury shines brightly (magnitude 0.1), however, and you should be able to see it in the twilight glow through binoculars. A telescope reveals its disk, which spans 7" and appears slightly more than half-lit. If you have exceptionally clear skies September 14, you might spot Mercury 7° to the left of a waxing crescent Moon.

**Saturn** is a much more attractive target for evening

**Martin Ratcliffe** *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*




**The bluish outer planet reached opposition in late August and remains a tempting target during September. This amateur image also captures the planet's brightest moon, Triton, at upper left.** RON WARNER

# RISINGMOON

## Lunar ray of a different stripe

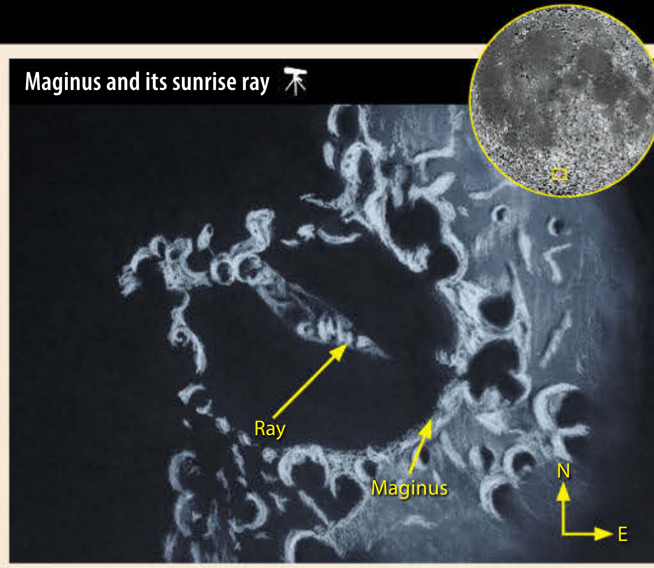
There should be a ray of hope (OK, sunshine) spreading across the floor of the battered crater Maginus on the evening of September 20. This 100-mile-wide impact feature sports a bulged-up floor, central mountain peaks, and a low rim. The last attribute is the most critical for the crater's appearance on the 20th because it allows a prominent V-shaped splay of sunlight to reach across the otherwise dark floor.

Like so many events in astronomy, timing is everything when it comes to seeing this ray. On the evening before, Maginus remains in complete darkness; by the evening after, the Sun has risen high enough to illuminate nearly the entire crater. For the best viewing, you might have to wait until late evening when the Moon dips low in the west. See "Catch some Moon rays" in the July *Astronomy* for more examples of sunrise and sunset rays.

Don't confuse the Maginus ray with the much more common ejecta rays best seen around Full Moon. The latter formed when large, relatively recent impacts excavated lighter-hued material and dispersed this debris in streaks across the Moon's face. The most spectacular ejecta rays spread from Maginus' northern neighbor, Tycho.

Maginus lies deep in the Moon's southern hemisphere at a latitude of –50°. It appears closer to the lunar limb than you might expect, however, thanks to the foreshortening effect of the globe curving away from us. For the same reason, circular craters near the limb appear oval.

By the time Full Moon — and a total eclipse — arrives September 27, the Sun lies high in the lunar sky and shadows have disappeared. All that remains of Maginus are subtle features for patient selenophiles.




**A normally inconspicuous crater in the southern highlands, Maginus comes alive at sunrise when a beam of light shines through its battered eastern wall.** THOMAS McCAGUE; INSET: NASA/GSFC/ASU

observers. The ringed planet stands nearly 20° above the southwestern horizon as darkness falls in mid-September and doesn't set until 10 P.M. local daylight time. A waxing crescent Moon points the way September 18 when it passes 3° north of Saturn.

At magnitude 0.6, the planet stands out against the backdrop of eastern Libra. Saturn's only rival in this area is magnitude 1.1 Antares, located 12° to the southeast in neighboring Scorpius.

The ringed world appears best through a telescope when it lies higher in the sky during the early evening hours. Any instrument will show the planet's 16"-diameter globe surrounded by a ring system that spans 37" and tilts 24° to our line of sight.

You also should see Titan in proximity to Saturn. This 8th-magnitude moon passes

— *Continued on page 42*

# METEORWATCH

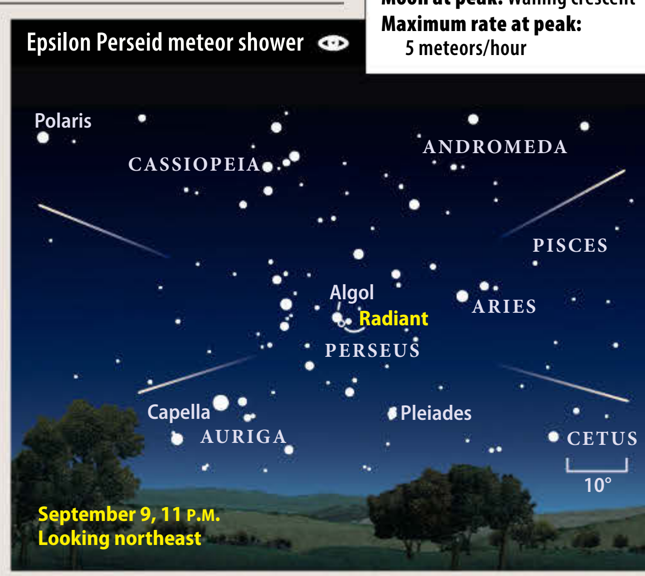
## A Perseus show two months in a row?

Because only a half dozen or so major meteor showers occur each year, observers often have to make due with minor events. That is the case in September. The best bet is the Epsilon Perseids, which burst on the scene with a slew of bright meteors in 2008 and delivered a similar display in 2013. In other years, however, the rate tops out at five meteors per hour.

The "shooting stars" appear to radiate from a point in Perseus near 2nd-magnitude Algol. For North American observers, the peak arrives the evening of September 9, though Perseus climbs highest just before dawn. A thin waning crescent Moon, which rises around 4 A.M. local daylight time, won't interfere at all.

**Epsilon Perseid meteors**

**Active Dates:** September 5–21
**Peak:** September 9
**Moon at peak:** Waning crescent
**Maximum rate at peak:** 5 meteors/hour




**Viewers could see up to five meteors per hour emanating from the constellation Perseus the night of September 9/10.**

ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

**OBSERVING HIGHLIGHT** On the night of September 27/28, observers across the Americas will see a 72-minute total eclipse of the Moon.

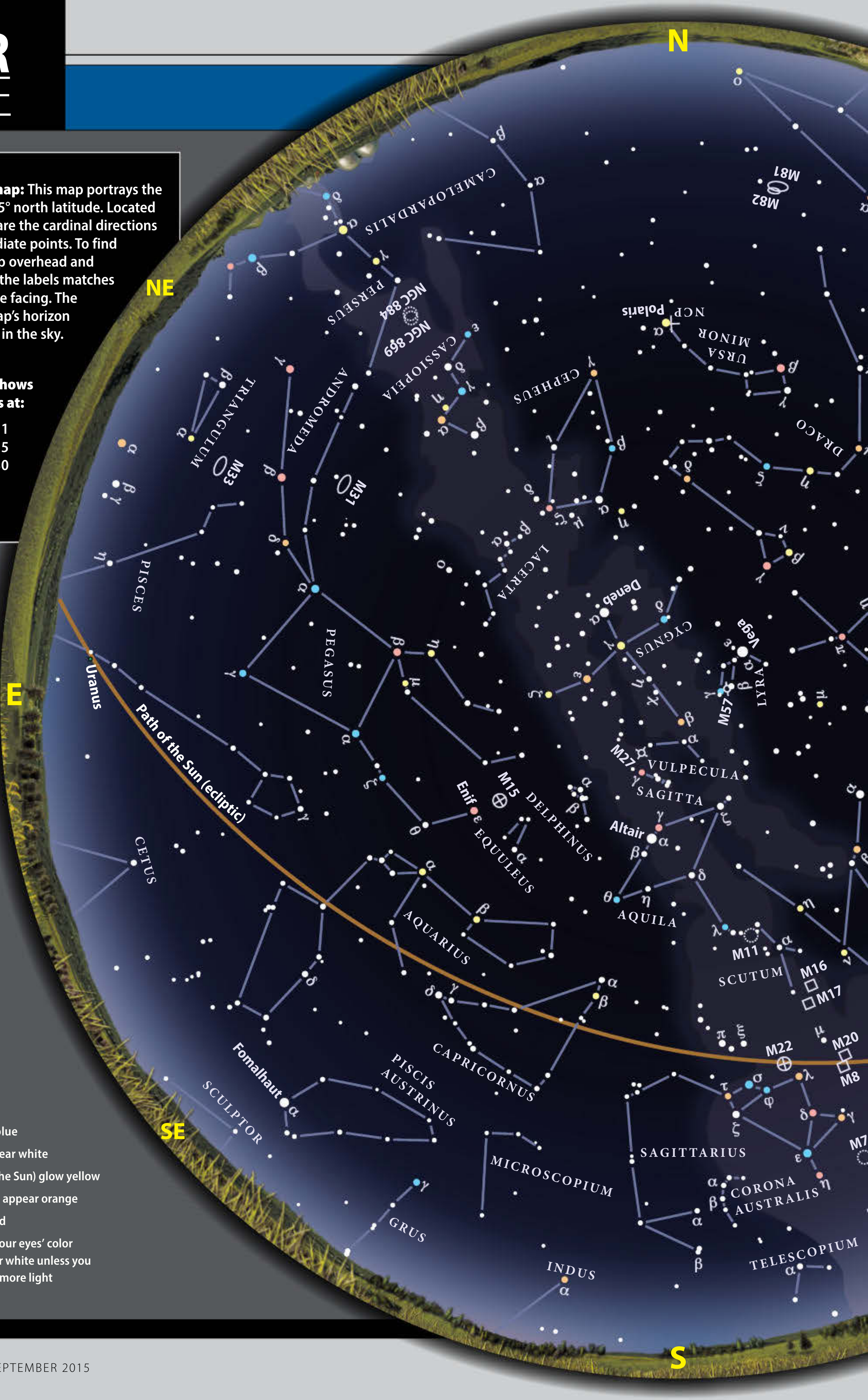
# STAR DOME

**How to use this map:** This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

**The all-sky map shows how the sky looks at:**

10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth




## STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

## STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light


**MAP SYMBOLS**

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy



# SEPTEMBER 2015

**Note:** Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

| SUN. | MON. | TUES. | WED. | THURS. | FRI. | SAT. |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | | | |

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

## Calendar of events

**1** The Moon passes 1.1° south of Uranus, noon EDT

**4** Mercury is at greatest eastern elongation (27°), 6 A.M. EDT

**5** The Moon passes 0.5° north of Aldebaran, 2 A.M. EDT

Venus is stationary, 5 A.M. EDT

Last Quarter Moon occurs at 5:54 A.M. EDT

Asteroid Metis is at opposition, 11 P.M. EDT

**10** The Moon passes 3° north of Venus, 2 A.M. EDT

The Moon passes 5° south of Mars, 7 P.M. EDT

**13** New Moon occurs at 2:41 A.M. EDT; partial solar eclipse

**14** The Moon is at apogee (252,565 miles from Earth), 7:27 A.M. EDT

**15** The Moon passes 5° north of Mercury, 2 A.M. EDT

Asteroid Ceres is stationary, 2 P.M. EDT

**17** Mercury is stationary, 9 A.M. EDT

**18** The Moon passes 3° north of Saturn, 11 P.M. EDT

**21** First Quarter Moon occurs at 4:59 A.M. EDT

**SPECIAL OBSERVING DATE**

**21** Venus gleams at magnitude –4.8 today, the brightest it gets during this morning apparition.

**23** Autumnal equinox occurs at 4:21 A.M. EDT

**24** Mars passes 0.8° north of Regulus, 1 P.M. EDT

Pluto is stationary, 3 P.M. EDT

**26** The Moon passes 3° north of Neptune, 6 A.M. EDT

Asteroid Juno is in conjunction with the Sun, midnight EDT

**27** The Moon is at perigee (221,753 miles from Earth), 9:46 P.M. EDT

Full Moon occurs at 10:50 P.M. EDT; total lunar eclipse

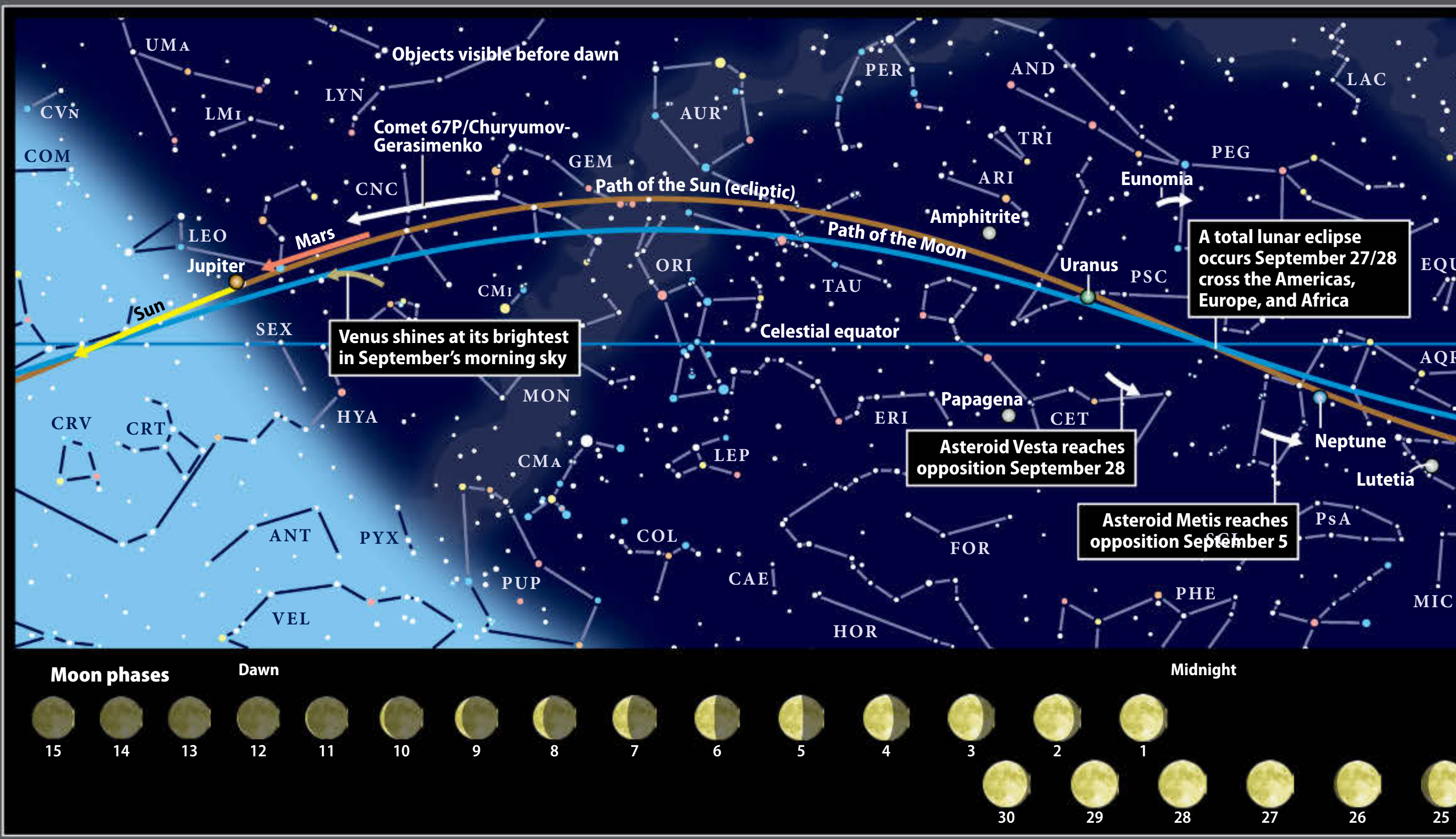
**28** The Moon passes 1.0° south of Uranus, 9 P.M. EDT

Asteroid Vesta is at opposition, 11 P.M. EDT

**30** Mercury is in inferior conjunction, 11 A.M. EDT

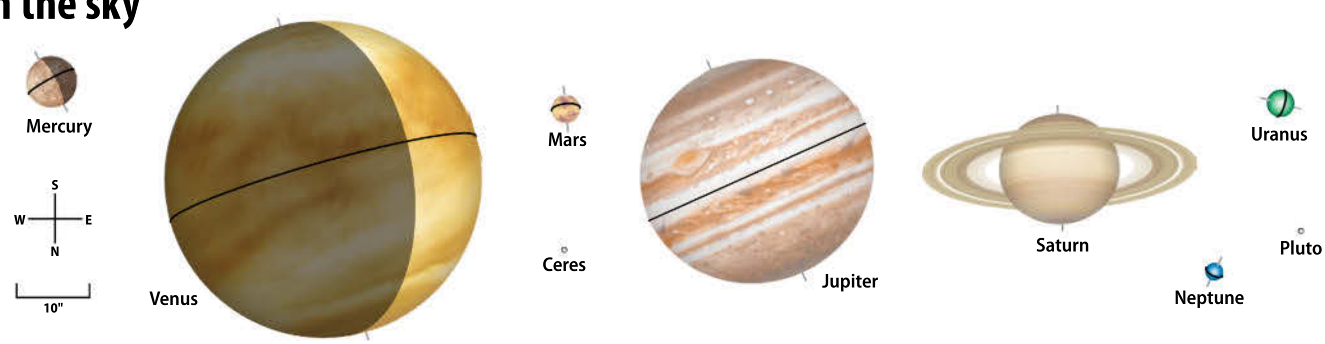
BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

# The planets in September 2015




## The planets in the sky

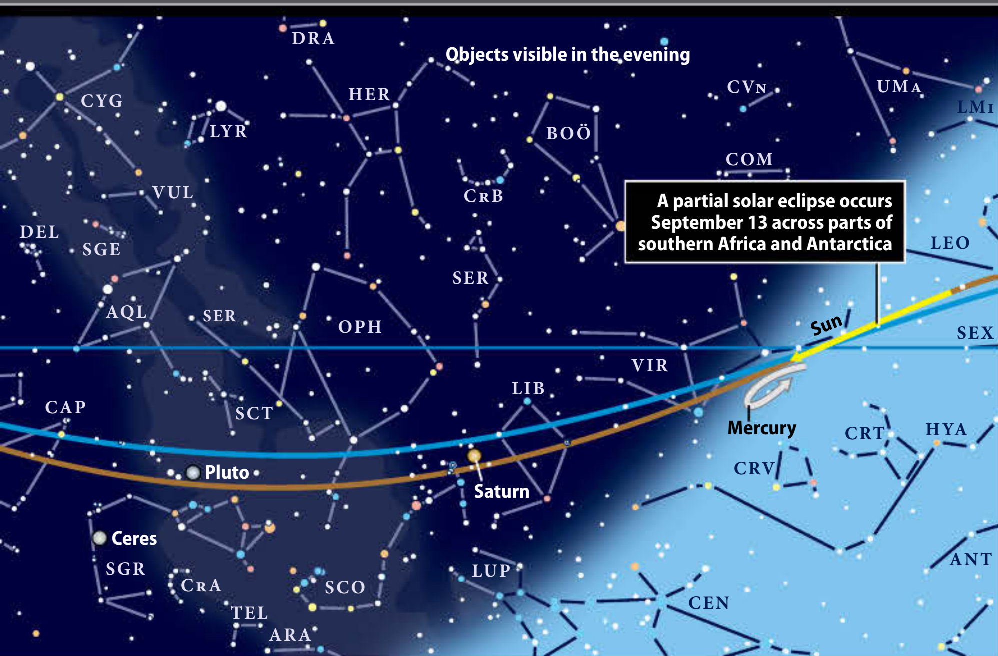
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.



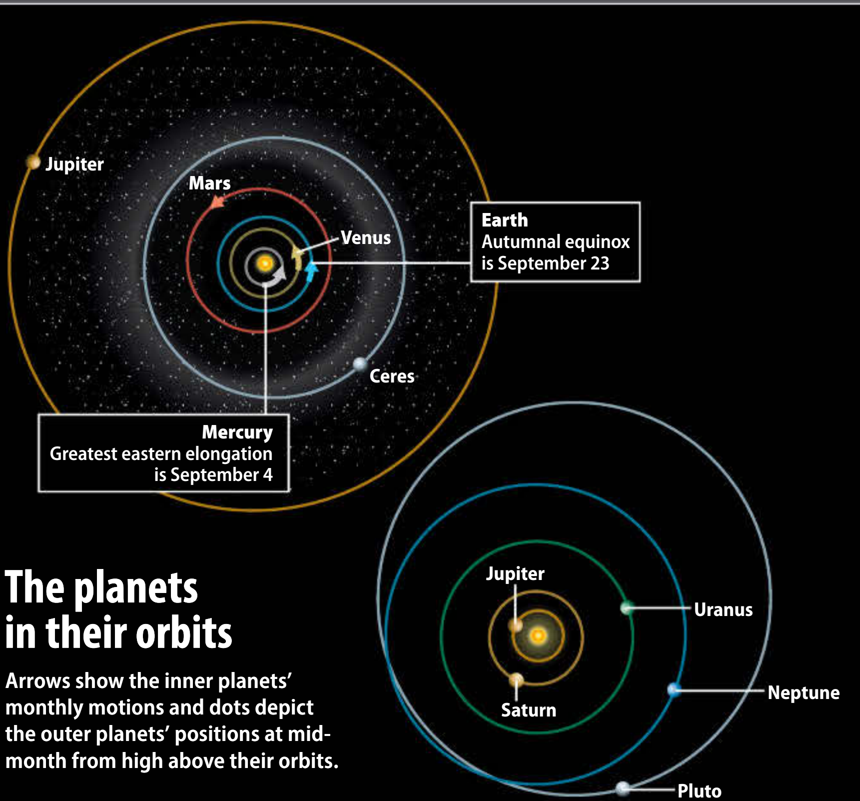

| Planets | MERCURY | VENUS | MARS | CERES | JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|---|---|---|---|---|
| Date | Sept. 1 | Sept. 15 | Sept. 15 | Sept. 15 | Sept. 15 | Sept. 15 | Sept. 15 | Sept. 15 | Sept. 15 |
| Magnitude | 0.1 | –4.8 | 1.8 | 8.4 | –1.7 | 0.6 | 5.7 | 7.8 | 14.2 |
| Angular size | 6.8" | 42.0" | 3.8" | 0.6" | 31.0" | 16.1" | 3.7" | 2.4" | 0.1" |
| Illumination | 60% | 22% | 98% | 98% | 100% | 100% | 100% | 100% | 100% |
| Distance (AU) from Earth | 0.994 | 0.397 | 2.460 | 2.296 | 6.361 | 10.330 | 19.089 | 28.985 | 32.571 |
| Distance (AU) from Sun | 0.466 | 0.726 | 1.644 | 2.962 | 5.393 | 9.996 | 19.985 | 29.962 | 32.947 |
| Right ascension (2000.0) | 12h14.9m | 9h05.2m | 9h44.7m | 19h56.3m | 10h37.2m | 15h51.1m | 1h12.4m | 22h39.1m | 18h54.8m |
| Declination (2000.0) | –3°40' | 10°44' | 14°51' | –31°41' | 9°40' | –18°18' | 6°57' | –9°24' | –21°00' |

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine




To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
**Note:** Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

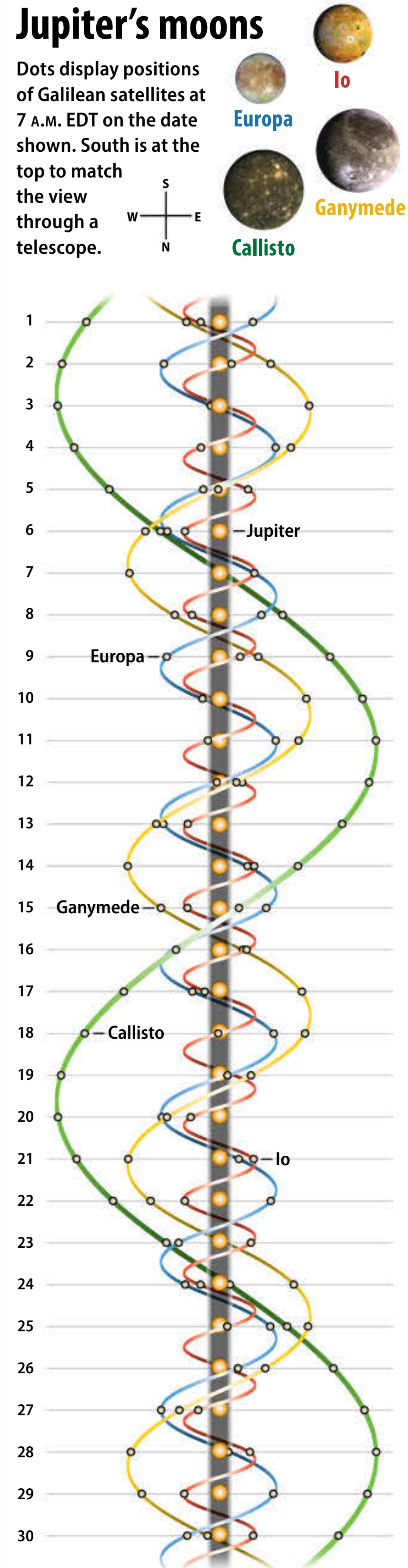




## The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

## Jupiter's moons

Dots display positions of Galilean satellites at 7 A.M. EDT on the date shown. South is at the top to match the view through a telescope.




ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

— Continued from page 37

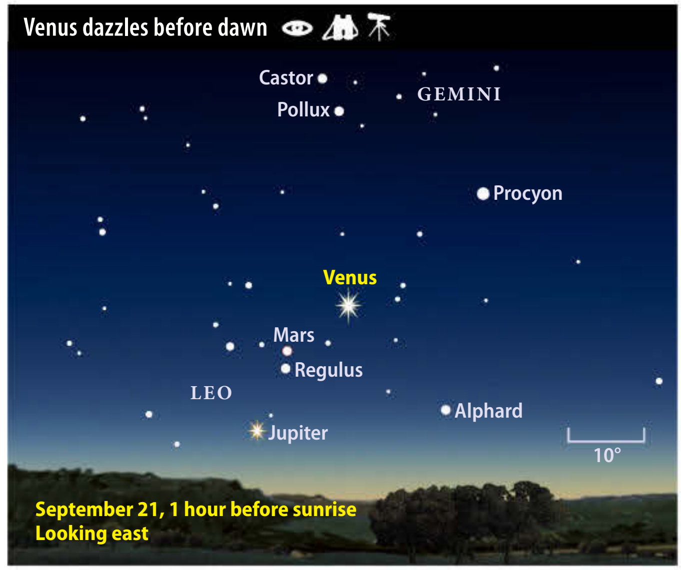
## WHEN TO VIEW THE PLANETS

| EVENING SKY | MIDNIGHT | MORNING SKY |
|---|---|---|
| Mercury (west) | Uranus (southeast) | Venus (east) |
| Saturn (southwest) | Neptune (south) | Mars (east) |
| Neptune (southeast) | | Jupiter (east) |
| | | Uranus (southwest) |

due north of the planet September 7 and 23 and due south on the 15th. A trio of 10th-magnitude satellites — Tethys, Dione, and Rhea — orbit closer in and show up through 4-inch and larger scopes.

Remote and mysterious since its discovery 85 years ago, **Pluto** remains distant but is far less enigmatic thanks to the eagle-eyed sensors aboard NASA's New Horizons spacecraft. Experienced observers can spy the magnitude 14.2 dwarf planet north of the Teapot asterism in Sagittarius through an 8-inch or larger telescope. Fortunately, magnitude 3.5 Xi² (ξ²) Sagittarii lies nearby. Pluto spends September between 0.6° and 0.7° west of this star. Sketch or photograph the area, and return to it a few nights later. The "star" that moved is Pluto.

**Neptune** reached opposition and peak visibility on the final evening of August, and its appearance in September barely suffers. The planet appears in the southeast as darkness falls and climbs nearly halfway to the zenith in the southern sky as midnight approaches. You'll need binoculars or a telescope to spot its magnitude 7.8 glow among the background stars of central Aquarius.




**The morning "star" gleams at its brightest of the year September 21, though it remains a beacon all month.**

The ice giant world lies roughly midway between 4th-magnitude Lambda (λ) and 5th-magnitude Sigma (σ) Aquarii. Don't confuse Neptune with a nearby magnitude 6.9 star in early September. On the 4th, the planet slides 3.6' due north of this star. A telescope will help confirm Neptune's identity. Under moderate magnification and steady seeing, you'll see its 2.4"-diameter disk and blue-gray color.

As Neptune climbs higher in the southeastern sky, **Uranus** appears low in the

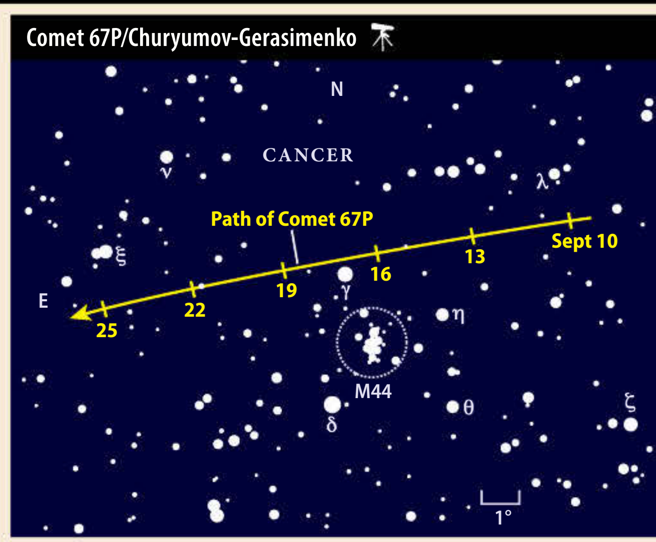
## COMETSEARCH

### Rosetta's target comes into view

Let's piggyback on the excitement stemming from the Rosetta spacecraft's ongoing encounter with Comet 67P/Churyumov-Gerasimenko by looking at the icy visitor with our own eyes. City and suburban lights will overwhelm the comet's fuzzy glow, so you'll need to observe under a dark sky. The object climbs highest in the east shortly before dawn. The best observing window opens as the waning Moon exits the morning sky around September 10 and lasts about two weeks.

Comets are notorious tricksters, even those like 67P that have returned to the inner solar system several times. Astronomers offer a wide range of predictions on how bright it will be, from a dim magnitude 10.5 to a feeble magnitude 13.5. If we're on the lucky side of these estimates, an 8-inch scope will pick it up nicely; if not, you'll need a 12-inch or larger instrument. In a final, ironic twist, we view the comet's dusty tail through the veil of debris left behind by countless other comets. Known as the zodiacal band, this soft glow envelops the path of the planets where 67P resides.

On September 10, you can find the comet 1° south of 6th-magnitude Lambda (λ) Cancri. The pair lies almost directly above the stunning conjunction of the crescent Moon and Venus. A week later, 67P passes 2° north of the Beehive star cluster (M44). Closest approach occurs the mornings of September 16 and 17. The 5th-magnitude star Gamma (γ) Cancri lies 0.4° south of the comet on the 17th.




**September provides a nice opportunity to spy this periodic comet from afar while the Rosetta spacecraft examines it from up close.**

There's a slim possibility that 67P could get upstaged by Comet 141P/Machholz if the latter ends its life with a major flare-up. Coincidentally, this dissolving ball of ice and dust is traveling in the same area of sky. The two comets cross paths September 1 when less than 1° separates them. Unfortunately, the Moon is just past Full phase then, making any visual observation a challenge even with Luna on the opposite side of the sky.

A partial eclipse for southern Africa

HINRICH BÄSEMANN

**Observers across the southern tier of African countries and parts of Antarctica can watch the Moon pass in front of the Sun on September 13.**

east. The seventh planet, which will reach opposition in mid-October, trails about two hours behind its more distant cousin. Uranus resides in a faint part of Pisces (although, let's face it, all of Pisces is faint), in the same binocular field as magnitude 5.2 Zeta (ζ) Piscium. You will find Zeta 17° east-southeast of Algenib (Gamma [γ] Pegasi), the star that forms the southeastern corner of the Great Square of Pegasus.

Once you locate Zeta through binoculars, Uranus should be a snap. On September 1, the planet lies 0.5° (the diameter of a Full Moon) due south of Zeta and about half that distance west-northwest of 88 Psc, a magnitude 6.0 star. Uranus shines at an intermediate magnitude of 5.7. The planet's westward motion relative to the starry background during September carries it to a position 1.2° southwest of Zeta by month's end.

If you target Uranus through a telescope, you'll immediately notice its non-stellar appearance. The world's disk spans 3.7" and has an obvious blue-green hue.

The relatively subtle pleasures of the overnight hours quickly give way to a dazzling display of three bright planets before dawn. **Venus** leads the way, rising before twilight commences and appearing far brighter than either **Mars** or **Jupiter**. Venus reaches its greatest brilliancy of the year September 21 when it shines at magnitude –4.8.

Fortunately, the ecliptic stands nearly straight up from the eastern horizon before dawn at this time of year, so angular distance from the Sun translates into altitude. How much difference does this make? Consider that Mercury lies 27° east of the Sun at greatest elongation September 4 but appears only 3° high a half-hour after sunset. On the same day, Venus stands 28° west of the Sun and climbs 16° above the eastern horizon 30 minutes before sunrise.

The beginning of September finds Venus in southern Cancer and Mars 9° to its north. A waning crescent Moon passes between the two worlds on the 10th; Jupiter adds to the spectacle when it rises an hour before the Sun.

Venus crosses from Cancer into Leo on September 24, coincidentally the same day Mars passes 0.8° due north of the Lion's luminary, 1st-magnitude Regulus. The Red Planet shines at magnitude 1.8 and offers a lovely color contrast with the slightly brighter blue-white star. Jupiter gleams at magnitude –1.7 just 10° below Mars. The gap between these two worlds tightens in late September; the pair will meet in mid-October.

The stunning naked-eye and binocular views of the three planets will garner lots of attention, but it's also worth targeting Venus through a telescope. On the 1st, its beautiful 9-percent-lit crescent measures 52" from cusp to cusp. By month's end, the planet's diameter shrinks to 33" and the Sun illuminates 34 percent of the disk.

Although Mars is too small (4" across) to show appreciable detail through a telescope, Jupiter spans a more impressive 31". You'll have a narrow window of visibility between the time it rises and the onset of bright twilight to view its dynamic cloud tops and four bright moons.

LOCATING**ASTEROIDS**

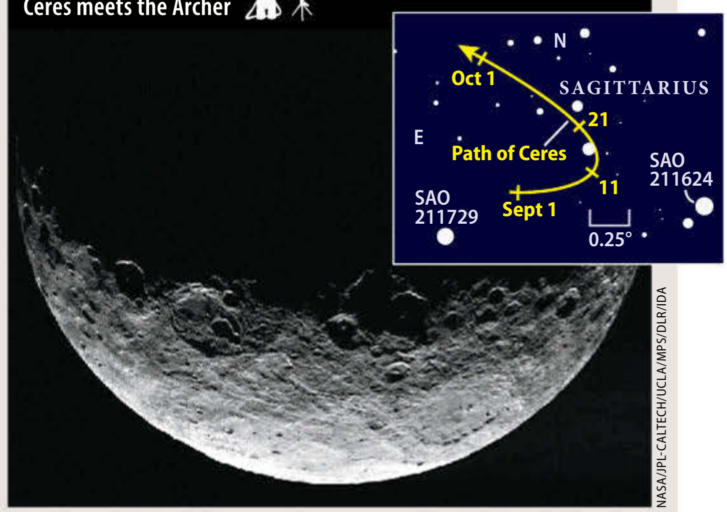
## A dwarf planet's looping stroll

Typically, the farther out in the solar system an object lies, the more leisurely it moves relative to the background stars. Because orbital motion slows dramatically in the outer reaches of our planetary system, it's rare to see a nearby object trudge along at an outer body's pace. But that's exactly what seems to happen in September when asteroid 1 Ceres (275 million miles from the Sun) traverses the same amount of sky as Uranus (1.86 billion miles away). Ceres still orbits the Sun at a faster speed than its cousin, but our line of sight from Earth makes the asteroid navigate a loop that extends barely 1°.

The upshot is that Ceres remains in the same field of view through a typical 4- or 6-inch telescope at low power. It lies in a sparse region of Sagittarius some 20° east of that constellation's Teapot asterism. The best time for hunting the asteroid is mid-evening, when the Archer climbs highest in the south.

Ceres fades from magnitude 8.2 to 8.7 during September. You'll find two noticeably brighter stars in the field — magnitude 7.1 SAO 211624 and magnitude 7.4 SAO 211729. Sketch the five or six brightest stars, and then come back a few nights later to locate the object that moved slightly — this is Ceres. The task is easiest around September 16 and 17 when the asteroid passes a nearly identical 8th-magnitude background star.

Ceres meets the Archer




NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

**While the Dawn spacecraft probes Ceres from orbit, Earth-based viewers can follow the asteroid's path through eastern Sagittarius (inset).**

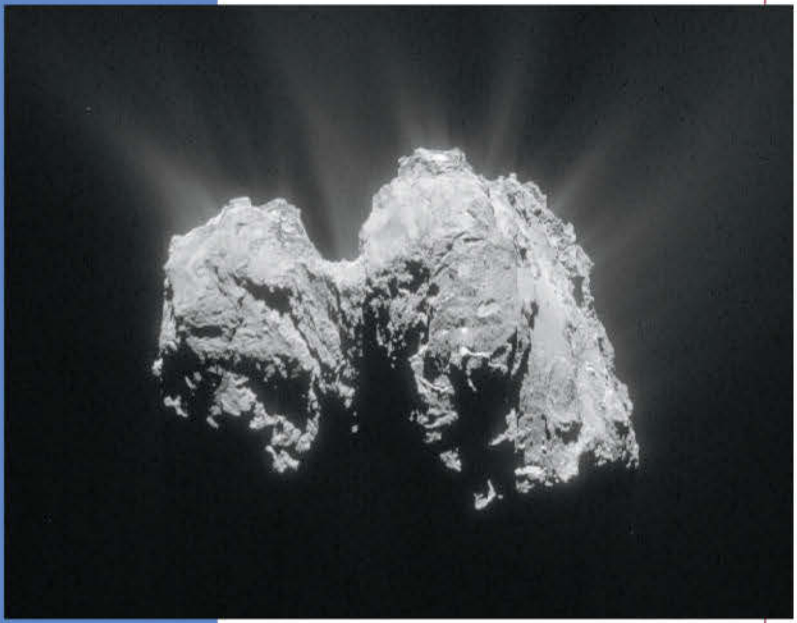
GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

# Rendezvous with an evolving COMET

The "neck" of Comet 67P/Churyumov-Gerasimenko looks slightly bluish in this false-color Rosetta image. Scientists think the color indicates areas of water ice at or just below the surface. ESA/ROSETTA/MPS/OSIRIS TEAM

# As Comet 67P/Churyumov-Gerasimenko heads closer to the Sun and grows more active, the Rosetta and Philae spacecraft scrutinize its complex behavior.

**by Richard Talcott**



**Comet activity was starting to ramp up nicely by early May, when Rosetta took this side-on view from a distance of 84 miles (135 kilometers).** ESA/ROSETTA/NAVCAM

On November 12, 2014, the European Space Agency's (ESA) Rosetta spacecraft jettisoned some of its most precious cargo. Rosetta, which had been orbiting Comet 67P/Churyumov-Gerasimenko ("67P" for short) for three months, released the Philae lander from an altitude of 14 miles (22.5 kilometers).

The washing machine-sized probe fell toward the comet for seven hours before touching the surface. Unfortunately, it didn't stick around. Philae was supposed to land on its three legs and then secure itself by shooting two harpoons into the comet, but they failed to fire. The probe was off to explore new frontiers.

Philae bounced off the surface at a speed of 15 inches (38 centimeters) per second, a significant fraction of the comet's escape velocity. But gravity won out, and the probe started to descend again. Data returned by the Rosetta Lander Magnetometer and Plasma Monitor (ROMAP) show that it hit the ground again about 45 minutes later. "We think that Philae probably touched a surface with one leg only — perhaps grazing a crater rim — and after that the lander was tumbling," said ROMAP co-principal investigator Hans-Ulrich Auster from the Technische Universität in Braunschweig, Germany, in November.

Philae embarked on another excursion, this one lasting 65 minutes and reaching an altitude of about 0.6 mile (1km). After hitting the surface a third time, the lander bounced several feet and then came to a stop. Unfortunately, it ended up in an awkward position — tipped on its side and in the shadow of a cliff.

**A LARGE CRACK** (part of which crosses the center of this image) runs across the comet's neck. ESA/ROSETTA/MPS/OSIRIS TEAM

**THIS HIGH CLIFF FACE** at the edge of the Hathor region reaches 330 feet (100 meters) high. ESA/ROSETTA/MPS/OSIRIS TEAM

## No time to waste

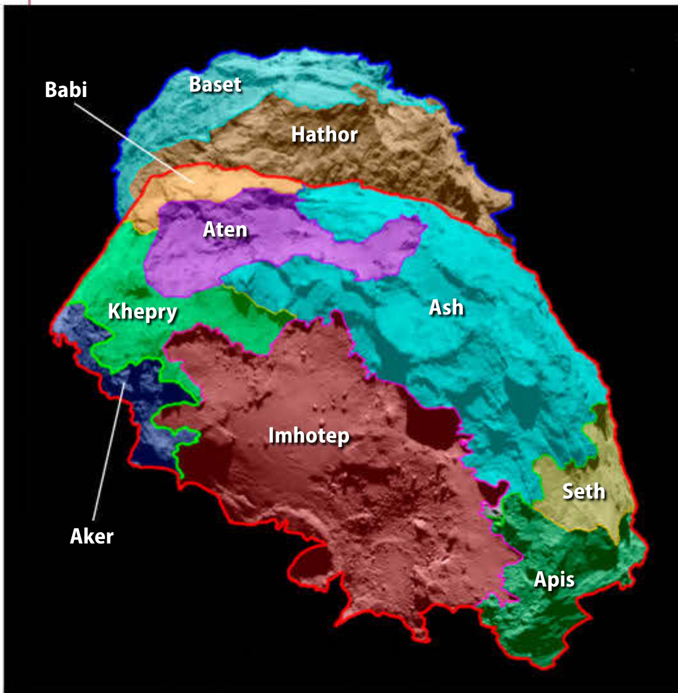
The cliff created a sense of urgency back on Earth. Mission planners designed Philae's battery to operate for about 60 hours. This pioneer comet lander's solar panels would recharge the battery continuously when they were in sunlight, however, allowing Philae to operate for several weeks or months.

But the deep shadows would not cooperate. The craft received only 1.5 hours of sunlight during each 12.4-hour day. It survived 57 hours on its battery power, during which it accomplished roughly 80 percent of what scientists had planned.

The probe's cameras photographed its surroundings. Some instruments sniffed 67P's atmosphere, finding molecules containing hydrogen and carbon. Others examined the comet's surface, which turned out to be as hard as ice in contrast to the "soft and fluffy" consistency scientists expected. But the shutters on one instrument failed to open and a drill on another could not penetrate the surface to deliver samples for onboard analysis.

As Philae neared its final hours November 14, controllers on Earth raised the craft 1.6 inches (4cm) and rotated it 35°. They hoped this would orient the

**Richard Talcott** *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*




**Rosetta scientists have identified 19 different regions on Comet 67P/Churyumov-Gerasimenko, 10 of which show up in this view looking from the comet's "body" toward its "head." In keeping with the ancient Egyptian theme used for both the Rosetta and Philae spacecraft, the regions are named for Egyptian deities.** ESA/ROSETTA/MPS/OSIRIS TEAM

largest solar panel so that as 67P neared the Sun in mid-2015, the added illumination would revive the probe.

The effort paid off. On June 13, Philae phoned home. The craft had survived its seven-month hibernation in great shape despite temperatures that dropped to around –240° F (–150° C). As this issue went to press in late June, Philae remained awake and alert, though it had yet to resume science activities.

## The view from above

While Philae rested, Rosetta did not stand idly by. The spacecraft — the first to orbit a comet — continues to reveal 67P in extraordinary detail. Mission controllers have adjusted its flight path many times to give both global and close-up views of the comet. The initial orbits had it about 60 miles (100km) from the comet. Later in 2014, Rosetta spent time in circular orbits 18 miles (29km), 11.6 miles (18.6km), and 6.1 miles (9.8km) from 67P's center.

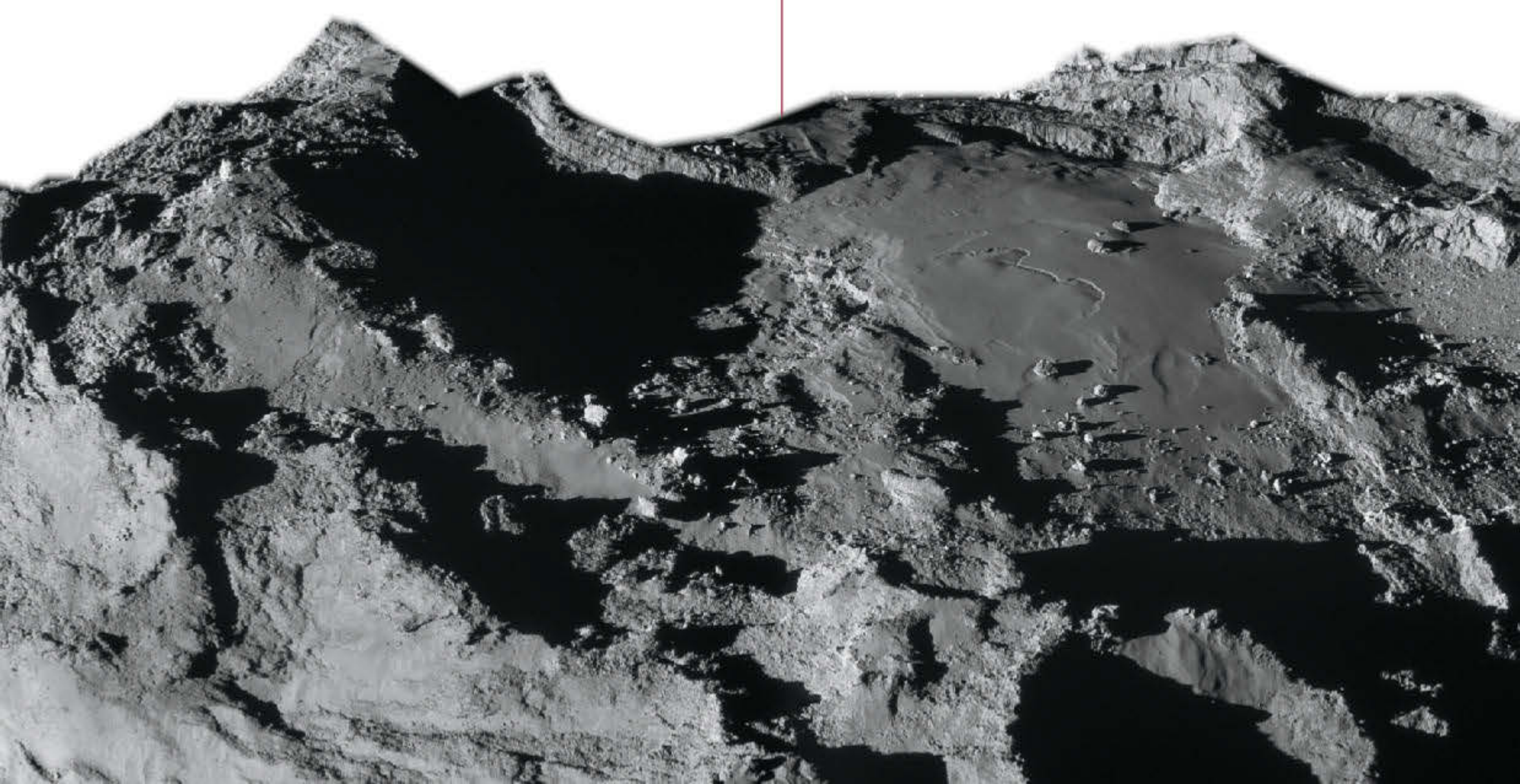
Afterward, Rosetta embarked on a series of close flybys, some dipping to within 4 miles (6km) of the surface. But in the months before 67P's August 13 perihelion — the comet's closest approach to the Sun in its 6.44-year orbit — Rosetta had to back off.

Like all comets, 67P grows more active as it nears the Sun. Our star's light heats ices on or just below the surface, causing them to turn directly from solids into gases in a process known as sublimation. As the gases escape in powerful jets, they carry with them dust particles and larger bits of rock embedded in the ice. These liberated substances form a tenuous atmosphere, or coma, as well as gas and dust tails.

It all proved a bit too much during Rosetta's close flyby in late March. The spacecraft uses "star trackers" to navigate and orient itself, but 67P's dust production grew so high that the trackers started mistaking cometary debris for stars. Hundreds of false stars confused the star trackers enough that Rosetta went into a "safe mode," switching off its science instruments and awaiting help from Earth. Mission controllers recovered the spacecraft within 24 hours but quickly moved it into a safer, more distant orbit.

Rosetta's first 10 months at 67P delivered exquisitely detailed information. The comet is a contact binary shaped like a "rubber ducky" with one large lobe (the "body") joined to a smaller lobe (the

**Rosetta captured this view of Comet 67P/Churyumov-Gerasimenko from a distance of 12.4 miles (19.9 kilometers) March 28. The two-image mosaic shows part of the comet's Imhotep region at a resolution of 5.6 feet (1.7 meters) per pixel.** ESA/ROSETTA/NAVCAM



"head") by a narrow "neck." The body measures 2.5 by 2.1 by 1.1 miles (4.1 by 3.3 by 1.8km) and the head spans 1.6 by 1.4 by 1.1 miles (2.6 by 2.3 by 1.8km).

More importantly, the mass and volume of 67P reveal that the comet has a density less than half that of water and a porosity — a measure of how much empty space lurks inside — of more than 60 percent. Dust in the nucleus outweighs ice by roughly four to one. And the surface is exceedingly dark, reflecting only about 6 percent of the sunlight hitting it, or half that of the Moon's surface.

Rosetta scientists argue that these stats suggest the nucleus is a mix of dust grains, organic compounds, and ice cemented together. Furthermore, they contend that the substances likely mimic the organic-rich soup created during the collapse of the solar nebula that gave birth to our solar system. If true, astronomers would be approaching a better understanding of the solar system's origin and evolution — one of the key reasons scientists wanted to send a mission to rendezvous with a comet. The Rosetta team bases these findings on orbiter observations of the gases released from the nucleus and stress that a Philae analysis of surface materials could change their thinking.

## A magnetic non-attraction

Rosetta has proven to be a trailblazer. For example, no previous spacecraft encounter yielded much information about cometary magnetic fields. From studies of meteorites, astronomers know that iron, some of it in the form of magnetite, existed in the solar system's earliest days. Some thought that magnetic fields might help matter clump together and build comets, asteroids, and other protoplanetary bodies.

But Philae's ROMAP instrument quashed this idea. The lander's bouncing trek actually improved the data. "If the surface was magnetized, we would have expected to see a clear increase in the magnetic field readings as we got closer to the surface," said Auster when reporting on the team's findings at an April meeting of the European Geosciences Union in Vienna, Austria. "But this was not the case at any of the locations we visited, so we conclude that Comet 67P/Churyumov-Gerasimenko is a remarkably non-magnetic object." The comet's magnetic signature instead derives from the solar wind, which carries the Sun's magnetic field throughout interplanetary space.

Close-up views of 67P also allow Rosetta to resolve the behavior of individual regions, something impossible to do from Earth. Since last September, the Microwave Instrument for the Rosetta Orbiter (MIRO) has studied the distribution of water molecules in the comet's coma. The team finds the highest concentration of water above the neck, where the density is up to 100 times larger than elsewhere.

**ROSETTA CAST ITS SHADOW** (bottom) onto the comet's surface from 4 miles (6 kilometers) up. ESA/ROSETTA/MPS/OSIRIS TEAM

**BOULDERS ABOUND** near the edge of the comet's broad and largely smooth Imhotep region. ESA/ROSETTA/MPS/OSIRIS TEAM

Significant amounts of water also exist across the comet's day side while little is on the night side.

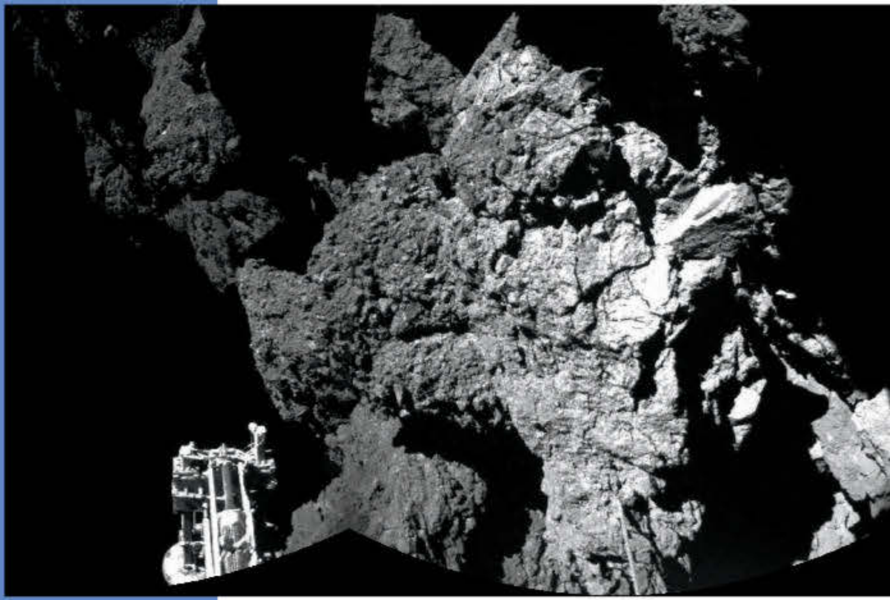
## Scientists: Rewrite the textbooks

For decades, astronomers have watched comet ices — frozen water and frozen carbon dioxide (dry ice), for example — sublimate. The gases created quickly break up into their constituent atoms. Most researchers thought that energetic solar photons did the job, but Rosetta data have made them change their tune.

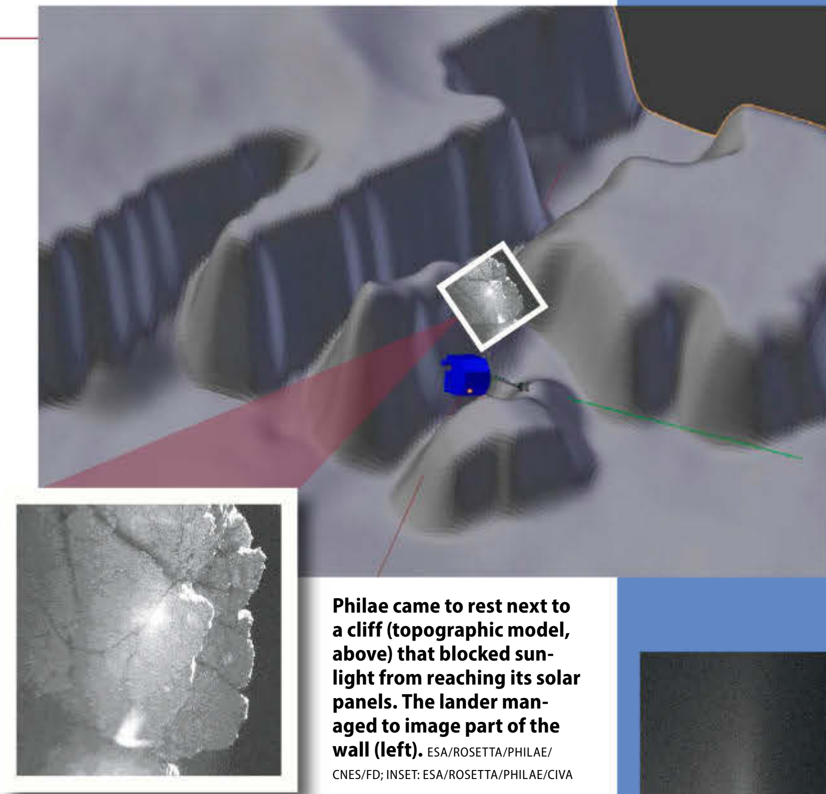
Observations made with the Alice spectrograph, an instrument that splits the comet's light into its component colors and thus allows scientists to identify the unique spectral fingerprints of coma gases, show the Sun needs a lot of help. Alice operates at far-ultraviolet wavelengths, where it can detect the hydrogen and oxygen atoms released from the breakup of water molecules and the carbon atoms freed from carbon dioxide molecules. (A similar Alice spectrograph flies on the New Horizons spacecraft that flew past Pluto in July.)

The Alice team found that the molecules split in a two-step process. First, a high-energy solar photon strikes a water molecule in the coma and strips an electron from it. The liberated electron then hits another water or carbon dioxide molecule and breaks it apart.

"The discovery we're reporting is quite unexpected," said S. Alan Stern, a planetary scientist at the



**The lander Philae set down on the comet's nucleus in November, where it operated for approximately 57 hours before entering hibernation. The two images contained in this mosaic, the first taken by Philae, recorded one of the lander's three feet (bottom left).** ESA/ROSETTA/PHILAE/CIVA



**Philae came to rest next to a cliff (topographic model, above) that blocked sunlight from reaching its solar panels. The lander managed to image part of the wall (left).** ESA/ROSETTA/PHILAE/CNES/FD; INSET: ESA/ROSETTA/PHILAE/CIVA

**GASEOUS PLUMES VENT** from the comet's nucleus June 15, just two months prior to perihelion. ESA/ROSETTA/NAVCAM

**SEVERAL JETS ERUPT** from the comet's small lobe just after the Sun set over the region. ESA/ROSETTA/MPS/OSIRIS TEAM

Southwest Research Institute in Boulder, Colorado, and Alice's principal investigator, in a June statement. "It shows us the value of going to comets to observe them up close, since this discovery simply could not have been made from Earth or Earth orbit with any existing or planned observatory."

Scientists also have learned that Comet 67P's weak gravity still has the power to hold onto cometary debris. At first blush, the jets spewing from the comet's surface seem strong enough to shoot any dust particles well beyond the nucleus' sphere of influence. After all, the dust tail forms when the weak pressure of solar radiation pushes away these ejected grains.

But Rosetta's main camera system, the Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS), targeted the motions of cometary particles located in a 12° by 12° area of sky. It tracked four debris pieces ranging from 6 inches (15cm) to 20 inches (50cm) across for which mission scientists could calculate orbits. Three of the particles apparently orbit 67P's nucleus and likely were ejected during the comet's last perihelion passage in 2009, while the fourth definitely is on an escape trajectory.

## An icy demeanor?

Sublimation of 67P's ices drives away many, but not all, dust particles — the comet's dark surface proves that. Some of the dust remains on the surface as ices underneath sublimate. But much more gets released slowly and then falls back somewhere else, covering the surface with a thin veneer and leaving little exposed ice. "A 1-millimeter-thick [0.04 inch] layer of dark dust is sufficient to hide the layers below from optical instruments," said Holger Sierks, OSIRIS principal investigator at the Max Planck Institute for Solar System Research in Göttingen, Germany, in a June statement.

But scientists using OSIRIS' narrow-angle camera did discover water ice in more than 100 patches on the comet's surface. These areas are typically several feet (a few meters) across and up to 10 times brighter than the surface average. Some occur in isolation, often on boulders that seem to have been transported from elsewhere. Others appear in clusters and usually lie in debris fields at cliff bases. These might be regions exposed by recent erosion or a cliff's collapse.

The researchers claim the bright areas must be water ice because that substance would be stable under the Sun's illumination at the observation time, while both carbon dioxide and carbon monoxide ices would have sublimated under the same sunlight. The bright patches should shrink or even disappear as the comet approaches perihelion, but new ones could appear in recently exposed areas.

## Second chances and longer looks

The next few months should provide a fascinating look at the changes a comet undergoes as it nears the Sun. Perihelion occurs in mid-August at a distance of 116 million miles (186 million km). With any luck, Philae should be operating throughout this period. After waking up June 13, the lander contacted Rosetta a half dozen times in the following 10 days, though the two craft still were trying to establish a reliable communications link.

Scientists know Philae's solar panels were receiving nearly three hours of sunlight each day and providing the probe with 24 watts of peak power, enough to raise its internal temperature to –31° F (–35° C). Those values should improve as the comet nears the Sun and the probe experiences more daylight hours.

Assuming that the communications problem gets ironed out, the science team will activate Philae's instruments in a specific order. The first to awaken will include ones that don't move and drain little power, such as those that measure temperatures and magnetic fields. Next up are ones that require a bit more power, which include the camera systems. Power-hungry instruments — in particular the two ovens that analyze the chemistry of comet samples — belong to the final group.

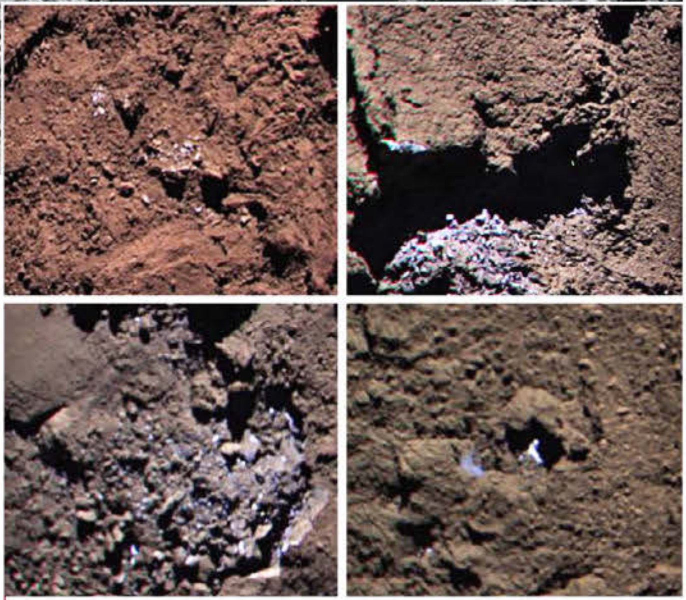
Philae scientists also may try to revive the drill if they can do so without upsetting the lander, which came to rest on its side. But some researchers think

Rosetta dipped within 4.9 miles (7.9 kilometers) of the comet's surface October 19 when it snapped this view looking across the object's "neck" from the small lobe toward the large one. ESA/ROSETTA/NAVCAM

dust may have made its way into the ovens during the probe's multiple bounces, so there may already be material ready to analyze.

Scientists got one final piece of good news June 23 when ESA announced it would extend the mission until the end of September 2016, nine months longer than originally planned. (Don't expect any further reprieves, however, because Rosetta will be nearly out of propellant by then and the Sun will be so distant that the solar panels won't deliver enough power.)

"This is fantastic news for science," said Rosetta project scientist Matt Taylor in a statement responding to the decision. "We'll be able to monitor the decline in the comet's activity as we move away from the Sun again, and we'll have the opportunity to fly closer to the comet to continue collecting more unique data. By comparing detailed before-and-after data, we'll have a much better understanding of how comets evolve during their lifetimes."



Although dust covers most of Comet 67P/Churyumov-Gerasimenko's surface, Rosetta has revealed more than 100 patches of water ice, including the four in these false-color images. ESA/ROSETTA/MPS/OSIRIS TEAM

FOR THE LATEST IMAGES AND SCIENCE FROM ROSETTA AND PHILAE, VISIT **www.Astronomy.com/toc.**

Cannibal star

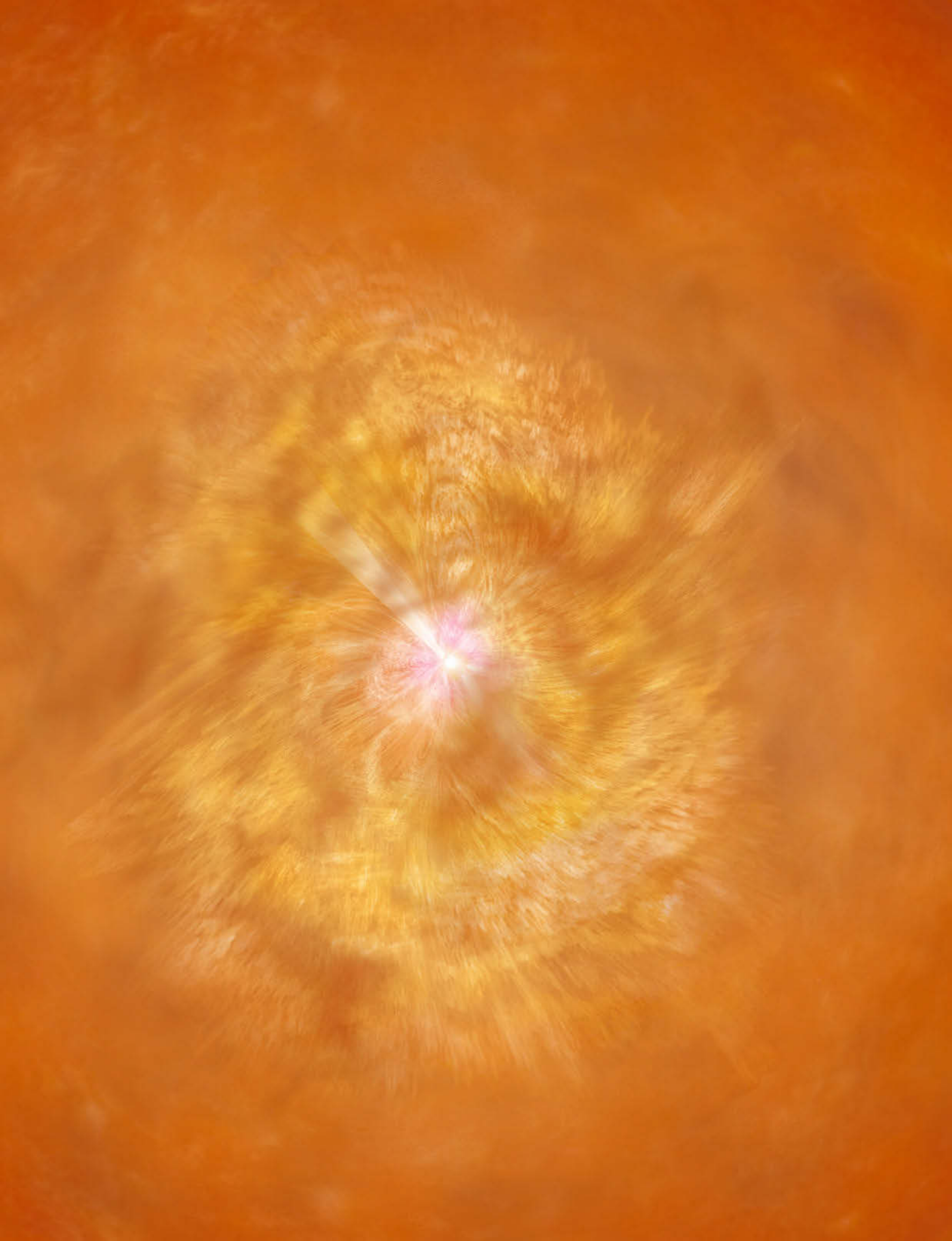
# The weirdest star in the universe

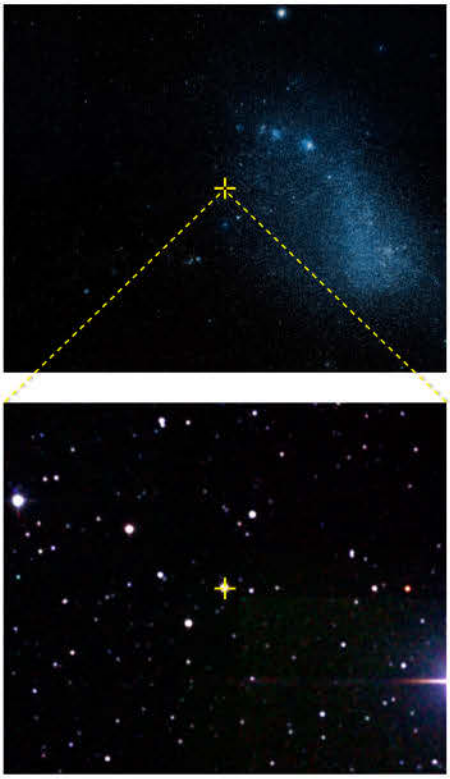
Astronomers dreamt up the idea of Thorne-Żytkow objects — dead stars inside dying stars — in the 1970s. Only recently have they tracked one down.

**by Yvette Cendes**

**In an infinite universe,** even the most bizarre thought experiments by astronomers — perhaps conceived late at night, perhaps proposed simply to see how weird stars can get — can come to pass. Imagine a massive star, near the end of its life and puffed up to the red supergiant phase, with a tiny neutron star, the skeletal remnant of an even more massive star, at its core. No one knows quite how this Frankenstar might form or how long it would live, and the fusion process would be anything but normal, yet the physics checks out. This mysterious star, called a Thorne-Żytkow object (TZO), could exist. But does it? Amazingly, 40 years after its conception, astronomers think they might have found one of these stars, and it has the potential to upend our understanding of stellar evolution.

**A neutron star — the tiny (not to scale here), mostly dead remnant of a massive star — hidden inside a dying red supergiant becomes an entirely new stellar oddity called a Thorne-Żytkow object.**
DON DIXON FOR *ASTRONOMY*





▲ **Emily Levesque and collaborators used the 6.5-meter Magellan II Clay Telescope at Las Campanas Observatory in La Serena, Chile, to observe the spectrum of HV 2112 and unlock its hidden nature as a Thorne-Żytkow object.** LAS CAMPANAS OBSERVATORY/CARNEGIE INSTITUTE OF WASHINGTON

◄ **At first glance, HV 2112 looks like an ordinary — if bright — red supergiant, shining clearly in this Spitzer infrared image of one corner of the Small Magellanic Cloud.** SPITZER/JPL/NASA/CENTER DE DONNÉES ASTRONOMIQUES DE STRASBOURG

## A working theory

TZOs are named after Kip Thorne and Anna Żytkow, two astronomers who worked out detailed calculations of what this strange system would look like in 1977 at the California Institute of Technology. They proposed a completely new class of star with a novel, functional model for a stellar interior. Scientists had explored the idea of stars with neutron star cores when neutron stars were first thought of in the 1930s, but their work lacked a detailed analysis or any firm conclusions.

The origin of a TZO goes like this: For reasons not yet clear, the majority of the massive stars we observe in the universe are in binary systems. These stars are several times more massive than our Sun (at least eight times bigger, though stars as large as hundreds of solar masses have been observed) and spend their fuel much more quickly. The largest stars in the universe burn all their fuel in just a few million years, while a star the size of our Sun burns for several billion. In a binary system where the two stars' masses are unequal, then, the larger of the two runs out of fuel and dies before its partner. The massive component explodes in a fiery supernova as bright as an entire galaxy. When the fireworks are over, this future TZO system is already exotic — the normal, lower-mass star is now paired with a rapidly rotating neutron star with a radius as tiny as 6 miles (10 kilometers), composed entirely of neutrons packed so tightly that they test the extremes of quantum mechanics.

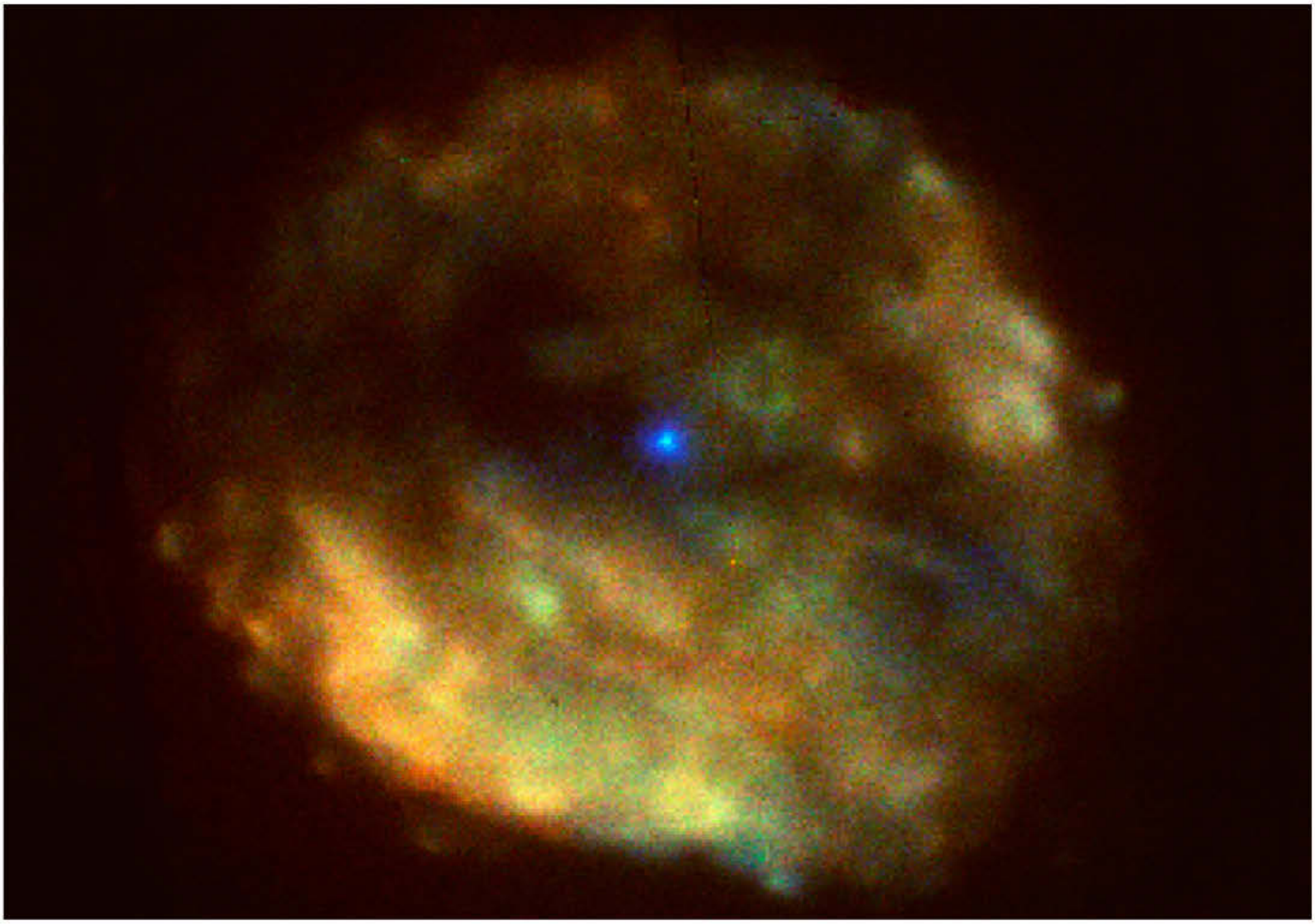
**TZOs are important because they have the potential to tell astronomers where some of the more exotic elements in the universe come from.**

Astronomers already have observed many such neutron star/normal star systems. As the two orbit each other, gas from the normal star can flow onto the outer layers of the neutron star, causing bright X-ray flares. These flares are millions of times more luminous than the X-rays emitted by normal stars and are in fact some of the brightest sources of X-rays in our galaxy.

But such systems raise a question: What ultimately happens to a system where a neutron star and a regular star orbit each other, but their orbits are unstable? This could occur for a variety of reasons, such as the supergiant's puffed-off gas layers dragging down the neutron star and causing it to spiral in or as a result of the supernova explosion that tore apart the first star. In many cases, the neutron star will get a gravitational "kick" that ejects it from the system. But for others, the binary system may reach a final stage of evolution wherein the neutron star orbits closer and closer to its companion, which by this stage is nearing the end of its own life and is a red supergiant star. Eventually, the two stars merge, the red supergiant swallowing the neutron star, and a TZO is born.

In a galaxy the size of our Milky Way, containing hundreds of billions of stars, such mergers should be happening routinely. In fact, scientists have proposed that as many as 1 percent of all red supergiants might actually be TZOs in disguise. "Mergers between a neutron star and a star are common," confirms Selma de Mink, an astronomer at the University of Amsterdam whose research focuses on stellar evolution. "The question is, what does that look like? For me, that is the big excitement — this happens all the time, but we have no clue." She explains that some sort of transient and observable event should occur at the moment of the merger — perhaps there is a flare of energy in the X-ray or a

**Yvette Cendes** *is a Ph.D. candidate in radio astronomy at the University of Amsterdam. She is on Twitter @whereisyvette.*



**This neutron star X-ray source hidden inside a supernova remnant stumped astronomers for years while they tried to explain its slow rotation period. The solution might in fact be that it is the "ghost" of a Thorne-Żytkow object.** SA/XMM-NEWTON/A. DE LUCA (INAF-IASF)

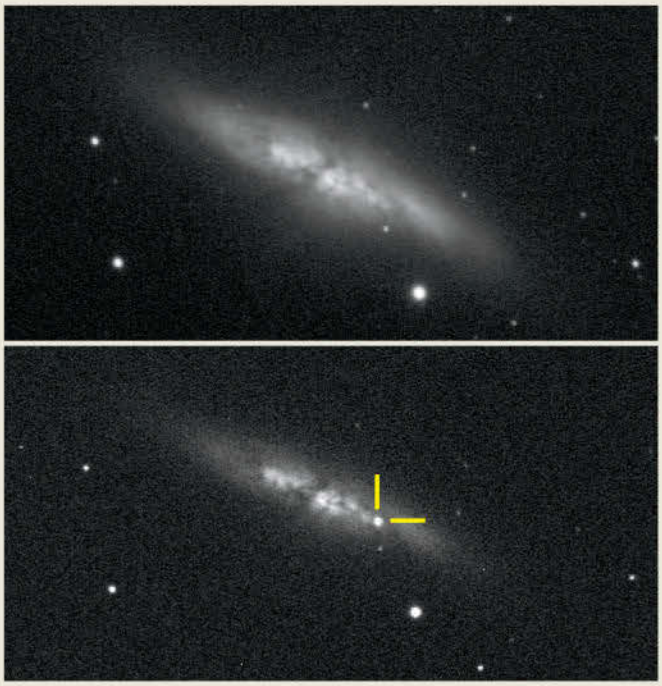
nova explosion in visible light. Theorists are working on various models, but as yet there is no consensus on what scientists would see at the birth of a TZO.

## Made of star stuff

TZOs are important because they have the potential to tell astronomers where some of the more exotic elements in the universe come from. Hydrogen, helium, and trace amounts of lithium were created immediately after the Big Bang. All the heavier elements in the universe, though, formed not at the dawn of the cosmos, but within the heart of a star. Some of these elements we know and love from our daily lives — carbon, oxygen, and iron, to name a few — are produced inside stars through regular processes that are fairly well understood. But the origin of some particularly heavy elements, such as molybdenum, yttrium, ruthenium, and rubidium, is less clear. "These elements are not household names, but still you might want to know where the atoms that make up our universe came from," jokes Philip Massey, an astronomer at Lowell Observatory in Arizona whose research includes the evolution of massive stars.

Theory suggests that these elements might be created in TZOs. A neutron star inside a red supergiant leads to an unusual method for energy production: The object's burning is dominated not by the standard nuclear fusion that occurs in other stars, but instead by thermonuclear reactions where the extremely hot edge of the neutron star touches the puffy supergiant's gas layers. These reactions power the star and also create those heavy elements. Convection that circulates hot gas in the star's outer layers transports these new elements throughout the star and ultimately even to its surface, where a keen-eyed observer with the right telescope might just spy them.

**The XMM-Newton satellite discovered the X-ray source scientists now believe may be the remnant of a Thorne-Żytkow object (shown above) after the red supergiant tore itself apart with its stellar winds.** ESA



**Astronomers saw a type Ia supernova explode in the relatively nearby Cigar Galaxy (M82) in January 2014. These two images were taken only a month apart and highlight the brilliance of the new supernova.** UCL/UNIVERSITY OF LONDON OBSERVATORY/STEVE FOSSEY/BEN COOKE/GUY POLLACK/MATTHEW WILDE/THOMAS WRIGHT

## DOUBLE STANDARDS

Binary stars end their lives in all kinds of dramatic and interesting ways, and as with all stars, the specifics of their stories depend mostly on the mass of the stars involved. Thorne-Żytkow objects (TZOs) may be astronomical oddities, but one of the most famous examples of binary stars that end their lives in an explosive and illuminating fashion resembles a TZO at two different stages. Type Ia supernovae are stellar explosions used as "standard candles," or distance indicators, by astronomers because they explode with a predictable amount of energy, which means their brightness varies neatly with their distance from us.

But two different kinds of binary systems give rise to these explosions. In one case, the system is a mass-mismatched binary, similar to but less extreme than the early stages of a TZO. The more massive star rushes through its lifetime but, instead of exploding, fades into a hot, dense white dwarf. The other star lags behind and, either as a Sun-like star or a red giant, starts to leak material onto its white dwarf companion. When the white dwarf has gorged itself on enough star stuff to overcome a precise 1.4-solar-mass limit, it explodes as a supernova.

In the other scenario, the two stars begin their lives more evenly matched and both progress to the white dwarf stage. As with TZOs, the exact catalyst is unknown, but something causes these partners to spiral toward one another and crash together, again lighting up in a supernova explosion.

While these may sound like very different events, from a distant spectator's point of view through a telescope, the differences between these two scenarios are subtle.

Astronomers are still working to figure out how many of our standard candles are caused by each of these processes. — *Korey Haynes*

## Hunting for TZOs

But tracking these mysterious objects down is not an easy task. "To an outside observer, TZOs look very much like extremely cool and luminous red supergiants," explains Żytkow, now at the Institute of Astronomy at the University of Cambridge in England. This means they are nearly indistinguishable from the thousands of other normal, bright supergiant stars that many surveys observe. "However, they are somewhat redder and brighter than stars such as Betelgeuse in the constellation Orion," she says, naming the famous red supergiant familiar to stargazers.

The only way to distinguish a TZO from a regular bright supergiant is to look at high-resolution spectra — patterns of light astronomers use as stellar fingerprints — to find the specific lines caused by the unusual elements more abundant in TZOs than in typical stars. Such work is severely complicated by the massive number of complex spectral lines from other elements and molecules in the star, which easily number in the thousands. "It is a needle in a haystack kind of problem," says de Mink.

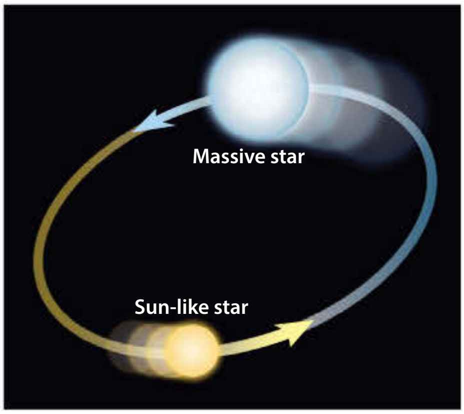
"Since we proposed our models of stars with neutron cores, people were not able to disprove our work. If theory is sound, experimental confirmation shows up sooner or later." — Anna Żytkow

Despite this, a team of astronomers thinks they might have found the first needle. Nearly four decades and several unsuccessful searches have passed since Żytkow initially worked on the theory behind TZOs. When she saw new research on some unusually behaving bright red supergiants, however, she was intrigued. Emily Levesque, an astronomer at the University of Colorado at Boulder, spearheaded the work with Massey, whom she has been researching red supergiants with ever since an undergraduate summer internship in 2004. Two years later, they discovered several red supergiant stars in the Magellanic Clouds — satellite galaxies of our own — that were unusually cool and variable in brightness. This avenue of research eventually attracted Żytkow's attention, so she asked whether the team had considered the possibility that these stars might be TZOs.

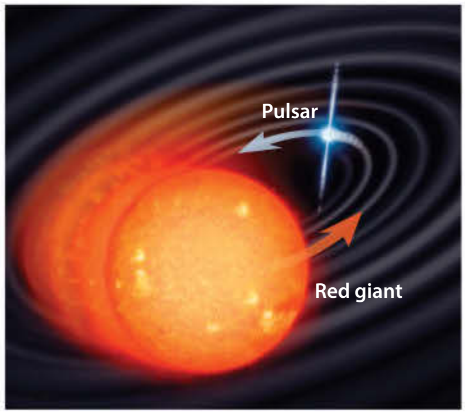
The potential to find the first TZO was exciting, but identifying a candidate from within the sample of red supergiants would require higher-resolution spectra than ever taken before. Levesque, along with her former mentor Massey and additional collaborator Nidia Morrell of the Carnegie Observatories in La Serena, Chile, secured time to observe a sample of several dozen red supergiants both in the Milky Way and in the Magellanic Clouds using the 3.5-meter telescope at Apache Point Observatory, New Mexico, and the 6.5-meter telescope at Las Campanas Observatory, Chile, respectively. They observed each of the stars with some of the most powerful spectrographs available and then began the meticulous task of identifying the various emission lines in the data and working out the relative elemental abundances in each star.

"It wasn't immediately obvious at a glance if we had a TZO," Levesque recalls, "but there was one star that jumped out at us." A star called HV 2112 in the Small Magellanic Cloud had a particularly bright hydrogen emission line astronomers saw even in the raw data they glanced at as it came in. In fact, it was so unusual that it prompted Morrell to joke at first look, "I don't know what it is, but I like it!"

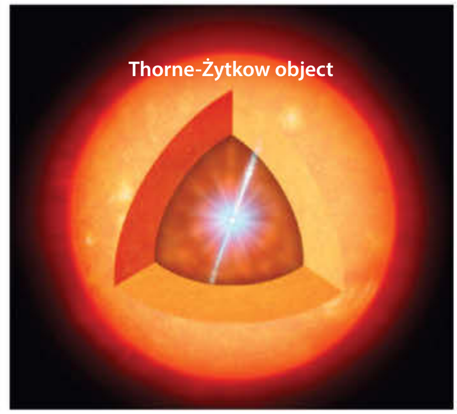
# How to make a TZO




A Thorne-Żytkow object (TZO) starts its life as a normal binary star. One partner is close in mass to the Sun while the other is significantly hotter and more massive (images not at all to scale). The heavier star burns through its fuel quickly and explodes as a supernova.




After the supernova, the massive partner leaves behind a tiny neutron star (even less to scale!). The Sun-like star consumes its hydrogen fuel more slowly and expands into a red supergiant. At some point, the stars' orbits become unstable, and they begin to spiral toward each other.




The stars circle each other on decreasing orbits until they merge. The moment of the merger should be observable, but astronomers aren't sure exactly what to look for. From most perspectives, the newly formed TZO now appears as a normal, if bright, red supergiant.

ASTRONOMY: ROEN KELLY

It turns out there was much more to like about HV 2112 — it had unusually high concentrations of the elements lithium, molybdenum, and rubidium, which are predicted TZO signatures. While finding a star with an unusual abundance of one key element can happen for a variety of reasons, this was the first time astronomers saw all the critical elements in the same star; the team published their results identifying HV 2112 as a TZO candidate in the summer of 2014. "It could still turn out not to be a TZO in the long run," explains Levesque, "but even if not, it's definitely a very weird star."

This discovery was also satisfying for Żytkow, who was instrumental in pushing for telescope time and analysis of the spectral lines. "Work on the discovery of a candidate object which Kip Thorne and I first predicted many years ago is great fun," Żytkow says. "Since we proposed our models of stars with neutron cores, people were not able to disprove our work. If theory is sound, experimental confirmation shows up sooner or later."

## Revisiting stellar evolution

While finding a "star within a star" sounds intriguing in itself, the discovery of a TZO is particularly interesting to astronomers for what its existence can tell them about stellar evolution. Major research advances in recent years in areas such as stellar convection allow astronomers to update their models for TZOs. These changes may yield new elemental abundances for observers to watch for. Astronomers also want to know whether TZOs can explain where some of the heavy elements come from: Rough estimates so far suggest there could be enough TZOs to explain their formation, but the numbers are highly uncertain.

With only one observed TZO in their stable, how do astronomers estimate how many TZOs are still in the wild, waiting to be discovered? This is not easy to answer: For one thing, no one is sure how long TZOs can be stable. Some models predict that they would be very short-lived objects — lasting only a few thousand years — either due to being torn apart by extremely strong stellar winds or collapsing into a black hole. "Computationally, this is one of the hardest things out there to model," says de Mink, "so we aren't sure."

Research also has focused on finding the remnant of a TZO after it has died. Recently, an international team of astronomers examined the abstrusely named X-ray source 1E161348–5055, which has perplexed scientists since its discovery several years ago. Initial results suggested its power comes from a neutron star — 1E161348–5055 is in fact located in a supernova remnant estimated to be just 2,000 years old — but its rotation period is 6.67 hours. Such a young neutron star should be rotating thousands of times faster; this slow period is more indicative of a neutron star that is several million years old. Several theories have been suggested over the years — perhaps the neutron star has a stellar companion, or perhaps it has an unusually high magnetic field — but no one has explained this mysterious X-ray source to everyone's satisfaction.

A TZO ghost may fit the bill. As a TZO, it might have burned for up to a million years. But a TZO's outer layers are not as dense as a normal star's, meaning this envelope of material is prone to dissipating over reasonably short time scales. The strong stellar wind common in larger stars could be all that's needed to blow the outer envelope away. This would leave behind a shell similar to a supernova remnant and a neutron star that is far older than its environment suggests — exactly what astronomers see in 1E161348–5055.

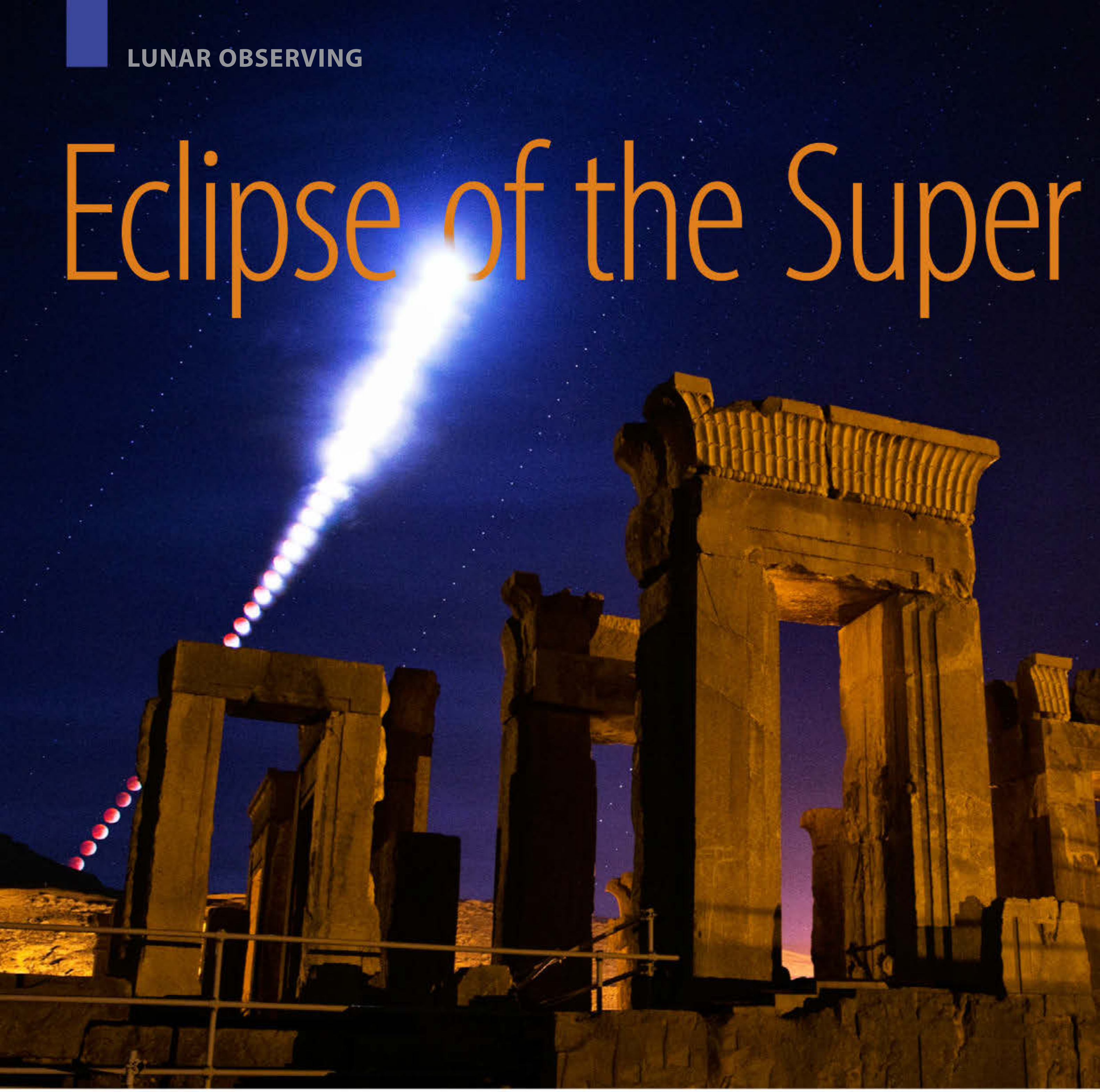
## Looking deeper

Astronomers also are considering whether some parts of our galactic neighborhood might be easier hunting grounds for TZOs. Globular clusters present a particularly appealing target. Stars in a globular cluster all formed around the same time, are densely packed, and are old, meaning they have few of the heavy elements that enrich newer stars. A crowded globular cluster hosts the ideal circumstances to give a neutron star the needed "kick" to merge with a red supergiant star, and the unusual spectroscopic lines would stand out more easily in the metal-poor population.

As spectrographs and telescopes improve and surveys probe ever deeper into our celestial surroundings, TZO-hunters will keep trying to learn more about these weird stars, how they form and how they die, and how many others are waiting to be discovered. As Levesque explains, "It is very exciting to see what's out there."

FOR ANOTHER WEIRD STAR, CHECK OUT A BINARY PULSAR KNOWN AS A BLACK WIDOW AT **www.Astronomy.com/toc.**

# Eclipse of the Super



During the total lunar eclipse December 10, 2011, this photographer captured a series of exposures that show the ever-brightening Moon rising and emerging from Earth's shadow. In the foreground are the ruins of the ancient city of Persepolis in modern Iran. FARZAD ASHKAR

IMAGINE A CRISP, CLEAR FALL EVENING: You are lounging among a few hundred fellow earthlings on an east-facing hillside as the largest Full Moon of the year rises above the horizon. A buzz circulates through the crowd as one by one, the Moon-gazers notice a shadow slowly sweeping across the lunar face. A total lunar eclipse completely transforms our satellite's appearance with subtle and shifting hues of gray, orange, and red. And the crowd goes wild!

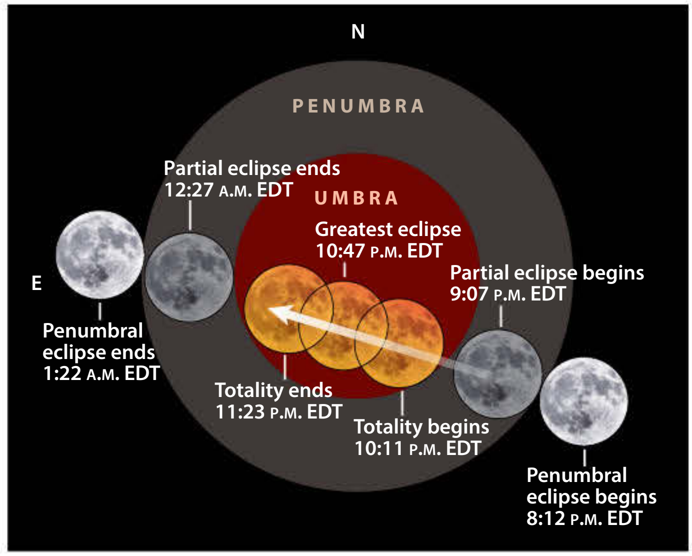
# Moon

*On September 27, the biggest Full Moon of the year will pass through Earth's shadow.*

**by Dean Regas**

This year, on the evening of Sunday, September 27, throughout North and South America, Europe, and Africa, people under a clear sky will witness a celestial event that will excite the media and engage the public. A total lunar eclipse will present its eerie glow during a perfect alignment of the Sun, Earth, and the Moon. Coincidentally, this also will be the night that the Super Moon, the Harvest Moon, and the last in a series of four eclipses that astronomers call a tetrad are on display.

These last three "events" may not be significant to astronomers, but they do prove so monumental to various forms of media that this night will surely become the foremost sky event of the year.




**The September 27 total eclipse of the Super Moon lasts a total of 5 hours and 10 minutes. The entire event will be visible from clear locations east of the Mississippi River and throughout South America and western Europe. More westerly locations in the U.S. will see progressively less of the eclipse.**

ASTRONOMY: ROEN KELLY, AFTER FRED ESPENAK/NASA

Subsequently, this is our call to action: This Super Moon/Harvest Moon/tetrad total lunar eclipse will present us with a rare opportunity to share our acute expertise and passion for astronomy with a wider audience. Let's get ready!

## Can you tell the difference?

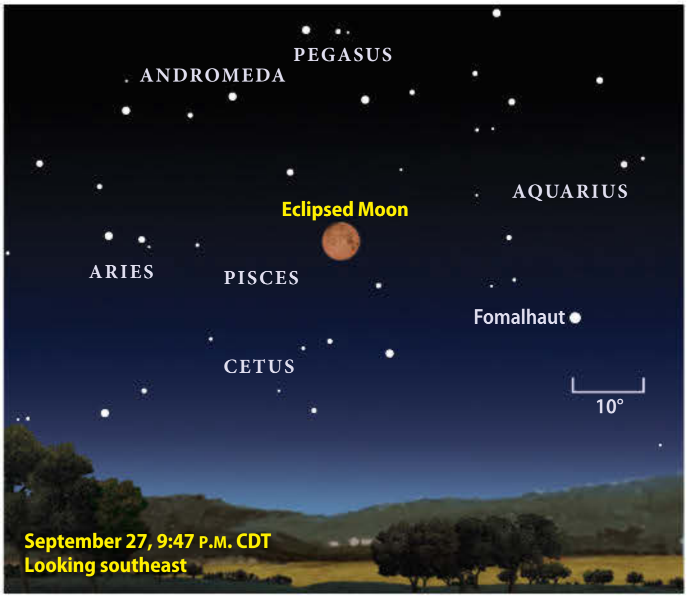
The public phenomenon called the Super Moon began in 2011 when online and mainstream media picked up on the obscure tidbit of knowledge that the Full Moon's distance from Earth varies. Many of my colleagues and I became instantly skeptical of this newfound interest in something astronomers refer to rarely (if ever) as a "perigee syzygy" — perigee meaning "closest to Earth" and syzygy meaning "a lineup of three celestial bodies."

Like all researchers, astronomers are naturally wary of the media when it comes to reporting so-called scientific stories. We have seen so many articles that overblow and embellish small discoveries, completely ignore large ones, garble the facts, or utterly miss the point. On the surface, the Super Moon seemed like yet another overhyped tale that would confuse and anger the public when they observed a Moon no larger than the one from their memories. But I was wrong. The media can handle a Super Moon, and the public simply loves it.

An observer using just his or her eye can't differentiate the Moon's apparent size from night to night. However, when one compares a Super Moon to the farthest Full Moon, a so-called "Puny Moon," the variance is dramatic. The Super Moon is more than 31,000 miles (50,000 kilometers) closer and consequently has a 14 percent larger diameter with a 30 percent larger surface area than

**This image of the penumbral lunar eclipse on October 18, 2013, shows what the early stages of the September 27 event will look like.**

CHUCK MANGES




**The totally eclipsed Super Moon on September 27 lies in southern Pisces the Fish, below the Great Square of Pegasus.** *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

the Puny Moon. That is like comparing a 16-inch pizza to a 14-inch pizza, or the sizes of a quarter and a nickel.

In the second century B.C., the Greek astronomer Hipparchus noticed this changing Moon size with his naked eye. He constructed a device called a diopter, a 6½-foot-long (2 meters) stick with a sighting circle on the far end. After utilizing the diopter through several lunar cycles, Hipparchus discovered that the Moon's angular size changed as it moved from perigee to apogee (its farthest point from Earth). Using simple geometry, Hipparchus compared the two extremes and discovered the proportional shift from a Super to a Puny Moon.

Nevertheless, celebrating a Super Moon and — even worse — creating a public event around it produces one of the biggest controversies in today's astronomy education. On the one hand, this is a non-event to astronomers, a moment that occurs once every 14 months and is neither dramatic nor scientifically significant.

On the other hand, the media and the general public eat it up. If astronomers create hype over this non-event just to satisfy the public interest, are they selling out?

## An astronomical holiday

The media love the Super Moon. It is a story they can understand, communicate well, and display graphically. All media platforms have broadcast the Super Moon successfully for the past four years. In 2011, the Cincinnati Observatory fielded so many calls about the Super Moon that I felt forced to meet public demand.

Still skeptical then, I begrudgingly scheduled an open house to view the Super Moon in 2012. What ultimately sold me was its timing. It would occur on a Saturday night in May, and a weekend night would maximize public attendance during a month known for ideal local weather conditions.

To my great surprise, hundreds attended. People gathered on the observatory's east-facing lawn and anxiously awaited moonrise over the verdant hillside.

To our credit, we managed the crowd's expectations well. People definitely weren't expecting a Moon twice as large as normal; rather they were simply thrilled to be outdoors with fellow stargazers and neighbors, watching a celestial dance on a beautiful spring evening. They stopped for longer than a moment to experience something in the heavens.

And then the Super Moon rose. It seemed hesitant at first, a delicate, faint glowing orb emerging from the spring haze. "I see it! I see it!" a first-grader jumped up shouting. "There it is," a woman in red whispered, "Oh, it's so beautiful."

I'd seen countless moonrises, but never before had I shared one with so many people. I looked around at the awed glowing faces basking in the moonlight. Parents held their children's hands or lifted them up onto their shoulders, pointing and smiling. Couples with arms entwined beamed. People kissed. The word "wow" reverberated through the crowd.

For an astronomer, watching others enjoy astronomy so much was as good as it gets. Finally, my emotions exploded, and I screamed out, "Super Moon!" at the top of my lungs. The crowd echoed with a howl of their own. We shared something with the universe that night.

The Cincinnati Observatory repeated this celebration June 22, 2013, and August 9, 2014, and twice more the power of the Super Moon moved me. We had even larger crowds lining the hillsides to observe together. Some were attending for the first time; others were loyal Super Moon enthusiasts. This festival of the Moon seemed to fill everyone with such joy.

Now I'm a Super Moon lover. Why not celebrate once a year and establish an event around something so beautiful? At first the Super Moon was an excuse to get people outside and looking up. Now it's not only a teachable moment but also a commemoration of our place in the universe. It should be an astronomical holiday.

## Perfect media event

The Super Moon of 2015 will go viral. Not only will the Full Moon on September 27 be the closest one of the year, but it also will be

**This photograph of the October 8, 2014, total lunar eclipse encapsulates the peacefulness of the event. Most lunar eclipses play out over hours, rather than minutes or seconds like some other astronomical events.** JOHN CHUMACK

**Because of the length of lunar eclipses, photographers have the opportunity to image each stage. This sequence records the total lunar eclipse of April 15, 2014.** RICHARD BRYANT

the Harvest Moon (the Full Moon closest to the September equinox) and complete a tetrad (a rare cycle of four total lunar eclipses in a row, each pair separated by about six months).

The media love coincidences, so social media might just explode. Religious types may interpret these events as signs from above, new doomsday prophets may foretell the end of all things, and history buffs may delve into old records looking for the last time this occurred.

In this case, any press that gets people to step outside that evening to behold an astronomical sight is good press. Say what you will about a Super Moon, but a lunar eclipse will not disappoint.

For viewers on the West Coast and in the mountain states of America, the Moon will rise already in partial eclipse just after dark, creating the perfect prime-time backdrop for a skyline or a national park. In the Midwest and East, Moon-gazers will have several hours to watch Luna arc above the eastern horizon and shift through its many eclipsing color variations. It surely will be shining in the background of the Denver Broncos at the Detroit Lions *Sunday Night Football* broadcast. Barring clouds, it will be viewed by millions of people.

## Plan for the astronomical event of 2015

Whether you're associated with an astronomy club, planetarium, science center, observatory, or just have an interest in astronomy, take advantage of this event. Host a Moon-watching celebration, an eclipse event, a lunatic block party, or a Super Moon extravaganza. Weather permitting, you will be guaranteed an enthusiastic audience, and this will be your chance to wow them.

Select a memorable viewing location so that the Moon will rise above a foreground of trees, a city skyline, or distinguishable local landmarks. Invite guests to bring lawn chairs, blankets, family, friends, and picnics. Hire a band. Interact with the crowd and answer questions, point out other astronomical objects in the sky, or introduce a telescope to share a closer look. For many people, this will be their first astronomical experience.

These opportunities challenge us as educators and enthusiasts. During this eclipse, we can turn passing interests into a memorable night and foster curiosity and delight in the field we love.

**Dean Regas** *is the astronomer at the Cincinnati Observatory and co-host of the PBS program* Star Gazers.

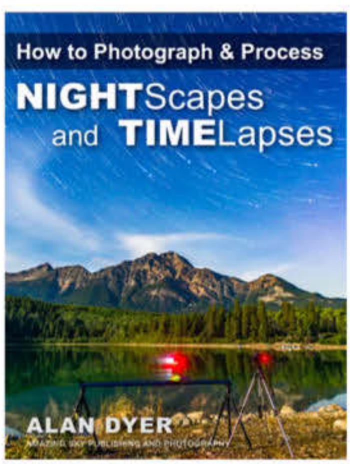
Astronomy magazine 2015 Star Products

# *Astronomy's* sixth annual STAR PRODUCTS

**by Phil Harrington**

Manufacturers from around the world continue to introduce innovative products that enhance the amateur astronomer's quality of life. Here are 35 noteworthy astro-wares, arranged in alphabetical order by manufacturer, that have caught the attention of our non-resident equipment expert during the past year.

## 1 AMAZING SKY PUBLISHING
### *Nightscapes and Timelapses*




Just as our hobby is changing in light of the digital age, publishing also is evolving. Embracing the revolution, Canadian author Alan Dyer has self-published the e-book *How to Photograph & Process Nightscapes and Timelapses* on wide-field astrophotography. As the title implies, the text focuses on shooting nighttime landscapes — stills as well as time-lapse movies — of the Moon and stars using DSLR cameras. But this is no ordinary e-book. Dyer includes many embedded videos and step-by-step tutorials covering cameras, software, and astronomy basics.


## 3 ASTRO-PHYSICS
### 1100GTO German Equatorial Mount

Astro-Physics is famous for fine refractors and rock-steady mounts. They don't come any better, and that includes the company's sturdy 1100GTO German Equatorial Mount. Designed for up to 8-inch refractors and 16-inch catadioptrics, the 1100GTO features internal cabling, error-free tracking, and zero backlash, all in a portable design. The 1100GTO allows for continued tracking past the meridian, an important plus for long-exposure imaging that can last many hours.

## 2 ARCTURUS LABS
### Magnifi

Many adapters allow you to couple your iPhone to your telescope for quick shots of the Moon, but only the Magnifi serves the dual purpose of adapter and case. A clever two-piece bayonet design locks the removable eyepiece adapter to the case with a simple counterclockwise twist. The manufacturer constructed the Magnifi from impact-resistant polycarbonate plastic and wrapped the phone's body with a stainless steel band.

## 4 ASTROSYSTEMS
### Dew Guard

Newtonians are great in damp environments because, unlike refractors and catadioptric instruments, their long tubes with no front lenses usually keep dew from forming on the optics. Unless your Newtonian doesn't have a tube, that is. Truss designs cool the mirrors faster but leave the optics exposed to dampness. While cloth light shrouds keep primary mirrors fog-free, secondary mirrors at the front of the truss remain susceptible. AstroSystems' Dew Guard secondary mirror heating system pastes a circuit board to the back side of the secondary to automatically sense the ambient air temperature and compare it to the mirror's temperature. It then maintains the secondary at an adjustable preset temperature just above that of the air. If you live in a damp environment, this could extend your viewing time for hours after everyone else has packed up.

## 5 CELESTRON
### Rowe-Ackermann Schmidt Astrograph

For those advanced deep-sky astrophotographers looking to augment their arsenal with a large-aperture, fast-focal-ratio system, Celestron's 11-inch "RASA" could be your next purchase. Optical designers Dave Rowe and Mark Ackermann have come up with an update to Celestron's classic Schmidt Camera that accepts both 42mm T-thread and 48mm camera adapters. This means that dedicated CCD imagers as well as popular DSLR cameras can produce outstanding results when coupled to this fast, large instrument.

**Phil Harrington** *is an* Astronomy *contributing editor and author of* Cosmic Challenge: The Ultimate Observing List for Amateurs *(Cambridge University Press, 2010).*

## 6 CELESTRON
### NexStar Evolution 9.25

Celestron's RASA is for photos only, but its new NexStar Evolution 9.25 is for everyone. As the name implies, this instrument raises the bar to the next level. The NexStar Evolution 9.25 is the first Schmidt-Cassegrain telescope with integrated Wi-Fi. That means you can forget a separate hand controller. Instead, the Evolution's built-in Wi-Fi syncs to your smartphone or tablet (iOS and Android), allowing you to control the night using Celestron's SkyPortal app. The built-in lithium-ion rechargeable battery promises up to 10 hours on a single charge.

## 7 CHATTANOOGA MILLWORKS
### ZLOMOTION

No doubt about it, manual Dobsonian mounts used with Newtonian reflectors are wonderfully simple to use — except when it comes to tracking. Enter the ZLOMOTION dual-axis slow-motion control system, available for most popular 8- to 12-inch instruments. By turning a pair of micro-adjustment knobs, the observer can slowly tweak the telescope's aim without losing a challenging object. To change vertical aim, the ZLOMOTION system uses a dual-rod device attached between telescope tube and ground board. Tweak the horizontal aim by twisting a second wheel attached to a belt-driven pulley system mounted to the base. To make large altitude changes, loosen a lock on the sleeve.

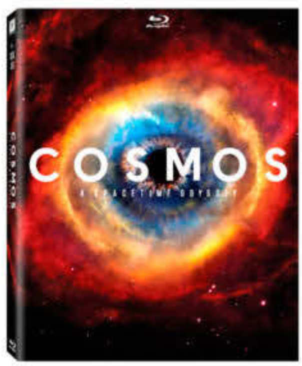
## 8 DAYSTAR INSTRUMENTS
### Quark

If you own a small f/4 to f/9 refractor and long for stunning views of solar prominences, filaments, and other chromospheric features, Daystar's all-in-one Quark Hydrogen-alpha (Hα) eyepiece filter is for you. The unit combines a 4.2x telecentric Barlow lens, adapters, and an electronically controlled, temperature-regulated Hα filter into one simple assembly that slips into your scope's focuser. Two models are available, one optimized for prominences and a second for the chromosphere.

## 9 EXPLORE SCIENTIFIC
### ▸ Twilight I

Explore Scientific's Twilight I alt-azimuth mount and included matching tripod make a perfect grab-and-go pair for a quick mid-week viewing session through your small- to medium-sized refractor or catadioptric scope. The combo has a payload capacity of 15 pounds (6.8kg) and mates with any telescope that uses a Vixen-style dovetail bracket. Further, you can tilt the mount's head to 45° for easier viewing near the zenith. Flexible cables attached to slow-motion controls on both axes turn smoothly and easily, even if you are wearing gloves.

## 10 FOX
### ▸ *Cosmos*




Rather than simply remake the classic Carl Sagan PBS miniseries *Cosmos*, Sagan's widow, Ann Druyan, and *Family Guy* creator Seth MacFarlane followed their own unique path for bringing the universe into our homes. Now available on Blu-ray, *Cosmos: A Spacetime Odyssey* uses spectacular imagery and well-written dialogue narrated by Neil deGrasse Tyson. The new *Cosmos* tells two stories: one about the universe and the other of how we humans continue to figure it out.

## 11 HOTECH
### ▸ Advanced CT Laser Collimator

There are plenty of laser collimators for reflectors, but few designed specifically for Schmidt-Cassegrains. HOTECH addresses this dilemma with its Advanced CT Laser Collimator. Consisting of three perfectly aligned lasers attached to a bull's-eye target, the beams simulate parallel rays of starlight. By installing the supplied Reflector Mirror into the focuser and aligning the target and telescope, the laser beams pass through the telescope twice and back onto the target. Adjust everything per the instructions, and you have a collimated telescope ready to go.


## 12 IOPTRON
### ▸ SkyGuider

All of iOptron's mounts are among the best sold today, including this portable equatorial dedicated to guided nightscape photography through your DSLR. Sharing some of the same mechanics as the company's iEQ25 telescope mount, the SkyGuider can track reasonably heavy cameras and lenses across the sky. You can attach ball heads to the mount's cradle as well as to the end of the counterweight shaft, allowing two cameras to operate simultaneously.

## 13 JMI TELESCOPES
### ▸ MOTOFOCUS

JMI is well known for its innovative accessories for all brands and models of telescopes. Recently, the company has expanded its line of MOTOFOCUS electric focusers to include retrofit kits for Crayford focusers made by Guan Sheng Optical, found on some of today's most popular instruments. The MOTOFOCUS attaches directly to the focuser without drilling. Once it's in place, just attach the hand controller to the MOTOFOCUS using the supplied coiled cable. A 9-volt battery in the controller powers the MOTOFOCUS' motor, while push-buttons on the box control the direction of focuser travel. A three-position switch adjusts the focusing speed.

## 14 KENDRICK ASTRO INSTRUMENTS
### ▸ Camera-Cozy

Does dew do you in when you're photographing the sky? Kendrick, known for its innovative anti-dew systems, now sells one designed to keep your camera lens clear of dew and frost-free all night. The Camera-Cozy includes a wrap-around heater strap for the lens, a controller to regulate temperature, and an unheated "body sock." The body sock slips over your DSLR to keep the internals dry but cool to prevent introducing image noise. Kendrick also offers several 12-volt battery packs to power the heater.

## 15 MALLINCAM
### Pro Dob II

Have a Dobsonian and want to try your hand at astrovideography? MallinCam's new Pro Dob II camera is designed with you in mind. Housed in a 2-inch-diameter tube, the Pro Dob II slides into your focuser just like an eyepiece. Powered by 12 volts DC, the Pro Dob II electronically triples a telescope's aperture, instantly displaying a color or black-and-white image (your choice) showing details invisible through an eyepiece. The company includes a specially designed 2" C-mount adapter and a 0.5x focal reducer, and sells an 8-inch LCD monitor separately.

## 16 NIKON
### D810A


Earlier this year, Nikon introduced its first DSLR camera designed specifically to capture the vivid Hydrogen-alpha (Hα) red wavelength (656 nanometers) so prevalent in emission nebulae. In the D810A, Nikon uses a specially constructed optical filter it attaches to the front surface of the camera's 36-megapixel CMOS sensor to gain four times greater transmission of Hα than its standard D810. The D810A, like its predecessor, can enlarge the live view through the lens up to approximately 23x for better focusing accuracy.

## 17 OPTIQUES FULLUM
### 50-inch telescope

Got aperture fever? Award-winning Canadian telescope maker Normand Fullum has the cure. Optiques Fullum makes custom telescopes, including a 50-inch f/3.5 folded Newtonian reflector. Fullum manufactures everything in-house, including the "Techno-Fusion" honeycombed primary mirror. The folded design, which adds a mirror between the primary and the elliptical secondary, lowers the height of the eyepiece by about 50 percent, which means most observers can reach the eyepiece by climbing only three steps. The open truss instrument comes equipped with the ServoCat/Argo Navis GoTo System. And despite the telescope weighing an estimated 1,400 pounds (635kg), a person can move it in altitude or azimuth with just one finger.


## 18 ORION
### EON 130mm ED Triplet Apochromatic Refractor Telescope

It's tough to design a telescope that satisfies the demands of astrophotography and produces great visual views of star clusters and nebulae, all while maintaining a down-to-earth price. But Orion's EON 130mm ED succeeds. The secret to its performance is the 5.1-inch air-spaced triplet lens made with extra-low dispersion glass. Its f/7 focal ratio suppresses spurious false color, while three internal baffles eliminate contrast-robbing reflections. The EON comes with a solid 3" dual-speed rack-and-pinion focuser, tube rings, and a custom-fitted hard case.

## 19 ORION
### Mini Deluxe Pro AutoGuider Package

One of the biggest obstacles to successful astrophotography is accurate tracking. Orion's Mini Deluxe Pro AutoGuider Package offers a solution for observers who use telescopes up to a focal length of 1,500mm. The heart of the system is a compact 50mm guide scope coupled to the company's StarShoot AutoGuider Pro monochromatic camera. This pair attaches to the side of the imaging telescope using a standard finder scope dovetail base, which Orion supplies. Weight isn't an issue, since the system adds a scant 21.2 ounces (600 grams) to your system. And tracking accuracy is excellent.

## 20 QUANTUM SCIENTIFIC IMAGING
### QSI 690


Quantum Scientific Imaging built its advanced line of QSI 690 cameras around Sony's 9.19-megapixel ICX814 CCD sensor. The ICX814 chip offers remarkable sensitivity with peak quantum efficiency (how much of the light gets captured) of more than 75 percent. That, coupled with its wide dynamic range, low noise, and available internal color filter wheel, integrated guider port, and mechanical shutter, makes the QSI 690 a great choice for anyone looking to take the next step into the realm of advanced astrophotography.

## 21 SCOPESTUFF
### RED Dot Finder for SLR Hotshoe

If you use a dedicated camera drive, such as Sky-Watcher USA's Star Adventurer (No. 23), then you know the challenge of aiming your camera toward a specific part of the sky. Images in viewfinders are just too faint to see much of anything. ScopeStuff offers a red dot finder that makes aiming a snap. The unit comes with a bracket designed to slip into an SLR's hotshoe base. Simply adjust the aim of the finder as you would on a telescope, secure the locking thumbnut at the base, and adjust the red dot's brightness to your liking.

## 22 SKY-WATCHER
### StarGate 18" Dobsonian

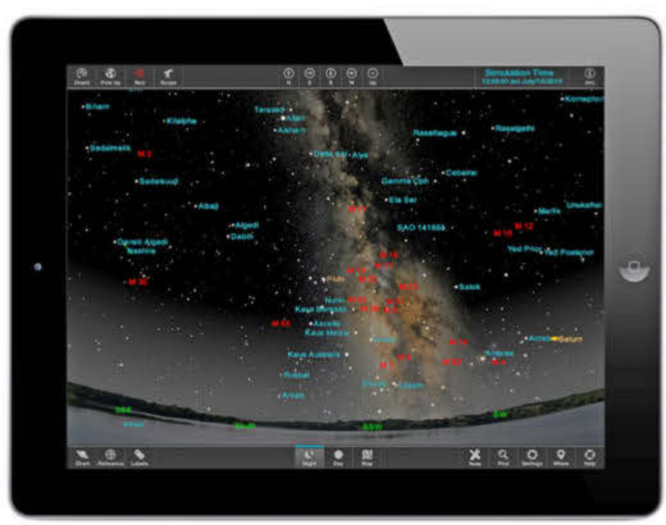
Sky-Watcher's new 18-inch f/4 Dobsonian packs a lot into little space. Its all-aluminum truss-tube design combined with a ribbed Pyrex primary mirror keeps weight to an absolute minimum. Standard accessories include a Crayford focuser, a right-angle finder, and a cloth light shroud. Word is that Sky-Watcher also will be offering a go-to upgrade kit in the near future.

## 23 SKY-WATCHER USA
### Star Adventurer Photo Package

Sky-Watcher USA designed its Star Adventurer Photo Package for creative astrophotography and time-lapse imaging. After a user attaches the Star Adventurer to a heavy-duty camera tripod (or optional equatorial base) and aligns it with the celestial pole, the Star Adventurer will track the sky at sidereal, solar, or lunar rates. It also offers automatic DSLR shutter-release control and includes other preprogrammed settings that allow you to create spectacular time-lapse videos.

## 24 SOFTWARE BISQUE
### TheSky Mobile

Many would say that the planetarium software market was born in 1983 when Software Bisque introduced *TheSky* for DOS. Today, several iterations later, *TheSky* has expanded into the mobile device market with the introduction of *TheSky* Mobile for iPhones and iPads. The product retains many popular features from the desktop version, including expandable object databases and field-of-view overlays, while also adding Wi-Fi telescope control that lets you operate your telescope directly from your device.




## 25 SONY
### α7S

This changes everything. With a 12-megapixel full-frame 35mm sensor, the Sony α7S is designed to shoot in extremely low light conditions at astronomically high ISO settings up to 409,600. Admittedly, there is a lot of "noise" at that extreme setting, but it allows you to set up a shot before shooting at a lower speed setting. At ISOs around 50,000 with quick exposures, unguided wide-field images taken with the α7S record amazing detail in Milky Way star fields. As astrophotographer Ian Norman said in his online review, "The α7S is so sensitive that it almost overexposed the Milky Way!"

## 26 STARGAZER STEVE
### 8-Inch f/6 Ultimate Reflector Kit

Telescope making used to be a mainstay of amateur astronomy. For those who still enjoy that creative aspect of our hobby, Steve "Stargazer Steve" Dodson, an award-winning telescope maker from Sudbury, Ontario, offers the 8-Inch f/6 Ultimate Reflector Kit. His unique product combines the advantages of a solid-tube telescope with the portability of truss-tube design. The kit includes the optics, cardboard tube, rack-and-pinion focuser, birch plywood mount, and Teflon bearings.

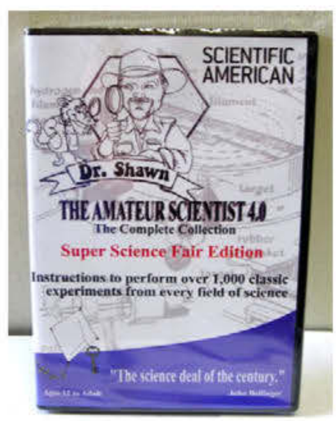
## 27 STARLIGHT XPRESS
### Lodestar X2 Autoguider

Sony's low-noise ICX829ALA EXview HAD CCD II detector powers Starlight Xpress' new Lodestar X2 imaging and autoguiding camera. Sensitivity is excellent, with an impressive quantum efficiency of 77 percent. The large 6.45mm by 4.75mm imaging area makes finding and acquiring a guide star easy. At the size of an eyepiece and weighing just 3 ounces (85g), the Lodestar X2 slips into a standard 1¼" focuser. Two connections are available, a USB 2.0 Mini interface for power and direct imaging and an RJ12 connector to accurately guide your mount.

## 28 STELLARVUE
### SV60EDS APO

With Stellarvue's new SV60EDS apochromatic refractor, small is big news. At the core of it all is a 2.4-inch f/5.5 doublet objective that features one element made from O'Hara FPL-53 glass. FPL-53 is well known as one of the finest materials for smothering unwanted chromatic aberration and boosting contrast. This little guy weighs a trim 3 pounds (1.4kg) and comes with a 2" dual-speed rack-and-pinion focuser, a mounting ring, and a foam-padded airline carry-on case. A photographic field flattener is available optionally.


## 29 SURPLUS SHED
### "The Amateur Scientist" on CD-ROM




For more than seven decades, *Scientific American* ran a regular column devoted to shade-tree scientists. Topics covered every field of science, from astronomy and archeology to chemistry and physics. Now, more than 1,000 of these, complete with original photos and diagrams, have been compiled on CD-ROM that works with Windows, Mac, Unix, and Linux. If you're a tinkerer, this is a must-have.

## 30 TAKAHASHI
### Quadriceps Turret Revolution

As with everything branded Takahashi, the Quadriceps Turret Revolution four-eyepiece holder is solidly made. The company intends the holder's 90° design for refractors and catadioptric telescopes. The turret threads onto the telescope's tailstock like any visual back and accepts up to four 1¼" eyepieces. To view through one of them, simply rotate the holder until the chosen eyepiece click-stops into position.

# ASTRONOMY'S STAR PRODUCTS

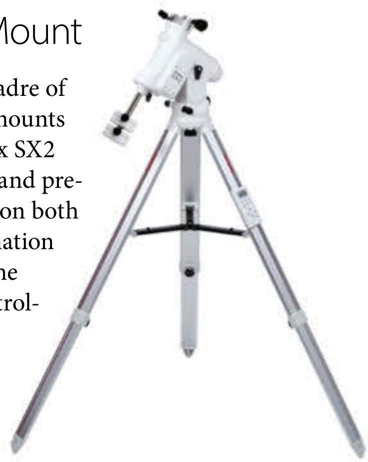
Astronomy magazine 2015 Star Products

| # | COMPANY | PRODUCT | PRICE | WEBSITE |
|---|---|---|---|---|
| 1 | Amazing Sky Publishing | ***Nightscapes and Timelapses*** | $24.99 | www.amazingsky.com |
| 2 | Arcturus Labs | **Magnifi** | $79.99 | www.arcturuslabs.com |
| 3 | Astro-Physics | **1100GTO German Equatorial Mount** | $8,800 | www.astro-physics.com |
| 4 | AstroSystems | **Dew Guard** | $37 to $47 | www.astrosystems.biz |
| 5 | Celestron | **Rowe-Ackermann Schmidt Astrograph** | $3,499.95 | www.celestron.com |
| 6 | Celestron | **NexStar Evolution 9.25** | $2,099.95 | www.celestron.com |
| 7 | Chattanooga Millworks | **ZLOMOTION** | $249 to $369 | www.zlomotion.com |
| 8 | Daystar Instruments | **Quark** | $995 | www.daystarfilters.com |
| 9 | Explore Scientific | **Twilight I** | $199.99 | www.explorescientific.com |
| 10 | FOX | ***Cosmos: A Spacetime Odyssey* Blu-ray** | $38.99 | www.foxconnect.com |
| 11 | HOTECH | **Advanced CT Laser Collimator** | $455 | www.hotechusa.com |
| 12 | iOptron | **SkyGuider** | $489 | www.ioptron.com |
| 13 | JMI Telescopes | **MOTOFOCUS** | $179 | www.jmitelescopes.com |
| 14 | Kendrick Astro Instruments | **Camera-Cozy** | $159 to $184 | www.kendrickastro.com |
| 15 | MallinCam | **Pro Dob II** | $399.99 | www.mallincam.net |
| 16 | Nikon | **D810A** | $3,799.95 | www.nikonusa.com |
| 17 | Optiques Fullum | **50-inch telescope** | $197,500 | www.normandfullumtelescope.com |
| 18 | Orion | **EON 130mm ED Triplet Apochromatic Refractor Telescope** | $2,999.99 | www.telescope.com |
| 19 | Orion | **Mini Deluxe Pro AutoGuider Package** | $519.99 | www.telescope.com |
| 20 | Quantum Scientific Imaging | **QSI 690** | $3,395 to $4,290 | www.qsimaging.com |
| 21 | ScopeStuff | **RED Dot Finder for SLR Hotshoe** | $31 | www.scopestuff.com |
| 22 | Sky-Watcher | **StarGate 18" Dobsonian** | £3,799 | www.skywatcher.com |
| 23 | Sky-Watcher USA | **Star Adventurer Photo Package** | $319 | www.skywatcherusa.com |
| 24 | Software Bisque | ***TheSky* Mobile** | $14.99 to $29.99 | www.bisque.com |
| 25 | Sony | **α7S** | $2,499.99 | www.sony.com |
| 26 | Stargazer Steve | **8-Inch f/6 Ultimate Reflector Kit** | $529 | www.stargazersteve.com |
| 27 | Starlight Xpress | **Lodestar X2 Autoguider** | $649 | www.sxccd.com |
| 28 | Stellarvue | **SV60EDS APO** | $599 | www.stellarvue.com |
| 29 | Surplus Shed | **"The Amateur Scientist" on CD-ROM** | $29.50 | www.surplusshed.com |
| 30 | Takahashi | **Quadriceps Turret Revolution** | $595 | www.takahashiamerica.com |
| 31 | Tele Vue Optics | **BIG Paracorr Type-2** | $1,060 | www.televue.com |
| 32 | Vixen Optics | **Sphinx SX2 Mount** | $1,399 | www.vixenoptics.com |
| 33 | Vixen Optics | **Astrograph VSD100F3.8** | $6,299 | www.vixenoptics.com |
| 34 | Waite Research | **Renegade 20** | $9,495 | www.waiteresearch.com |
| 35 | William Optics | **WO-Star71 Imaging APO** | $1,068 | www.williamoptics.com |

## 31 TELE VUE OPTICS
### BIG Paracorr Type-2

Owners of superfast Newtonians know that Tele Vue's Paracorr Type-2 coma corrector is a must-have for eliminating coma and improving image sharpness across the field of view. Now Tele Vue has heard the call of astrophotographers who want the same benefit across the full field of their large CCD chips. The BIG Paracorr Type-2 does just that. With a housing measuring 3 inches across, the BIG T2's optical design eliminates coma across CCDs measuring up to 52mm diagonally, with spectacular results. Adapters are also available to use the BIG T2 visually.

## 32 VIXEN OPTICS
### Sphinx SX2 Mount



Vixen's latest addition to its cadre of portable German equatorial mounts is the Sphinx SX2. The Sphinx SX2 offers complete go-to control and precise tracking. Stepper motors on both the right ascension and declination axes drive the mount, while the new Star Book One hand controller allows you to locate thousands of objects stored in the internal database. The mount can track the sky at sidereal, solar, lunar, and King rates, and slew to targets at up to 999x sidereal rate. Vixen included periodic error correction and a standard autoguider input. The SX2 also cleverly locates the drive motors so that they act as built-in counterweights. Small telescopes may require no additional counterweights.

## 33 VIXEN OPTICS
### Astrograph VSD100F3.8

Vixen's new VSD100F3.8 astrograph is a superfast imaging telescope designed with one thing in mind: to produce the best possible images of wide star fields and striking nebulosity. And it succeeds beautifully thanks to its advanced five-element objective lens design that includes a super-low dispersion lens in the front and an extra-low dispersion lens in the rear. Using those, the VSD100F3.8 achieves superb color correction. The blue halos so often seen around bright stars in photographs taken with traditional four-element objectives are gone. And for photographers who want to go big, the oversized focuser accepts 645 medium-format cameras without difficulty.


## 34 WAITE RESEARCH
### Renegade 20

Less is more when it comes to transporting and viewing through large-aperture Newtonians. Observers will have no need to ascend a tall ladder to enjoy the view through Waite Research's 20-inch f/3.3 minimalist Dobsonian-mounted reflector. Featuring the company's superb optics, Baltic Birch construction, and stainless steel hardware, the Renegade 20 includes high-end components such as a Starlight Feather Touch focuser, Moonlite truss hardware, an AstroSystems spider, and a Kendrick anti-dew system.

## 35 WILLIAM OPTICS
### WO-Star71 Imaging APO

Like the Vixen astrograph described earlier (No. 33), the William Optics WO-Star71 apochromatic refractor is built for astrophotography. Using FPL-53 glass for color-free performance, the WO-Star71's objective contains five elements in a three-group arrangement. The scope's 2.5" dual-speed rack-and-pinion focuser terminates in a male M48x0.75 thread that accepts camera T-mount adapter rings. For those amateur astronomers who want to use the scope visually, William Optics also sells a 1¼" dielectric mirror diagonal and adapter that threads onto the telescope's focuser tube.

ASTROSKETCHING

BY ERIKA RIX

# Sketch Minkowski's nebulae

The author sketched M1–64 here as seen through a 16-inch f/4.5 Newtonian reflector with a 8mm Plössl eyepiece and Oxygen-III filter, for a magnification of 225x. She sketched both targets using a Gelly Roll 08 white gel pen, a white watercolor pencil, white charcoal, a No. 1 blending stump, and black Strathmore Artagain paper. She used a gel pen to draw 3½-inch diameter sketch circles onto the paper. She removed the rough edges of the stars and added star glow in Adobe Photoshop. Sketches are rotated so that north is at the top, west is to the right. ALL SKETCHES BY ERIKA RIX

If you caught my previous column, you may have tried your hand at using the white-on-black sketching technique for deep-sky objects. Now it's time to step it up a notch. The challenge isn't always in the complexity of the object, but rather its size.

In 1946, a German-American astronomer named Rudolph Minkowski (1895–1976) released a new list of 103 nebulae. He discovered these by examining objective-prism survey plates obtained by William C. Miller with a 10-inch refractor at Mount Wilson Observatory.

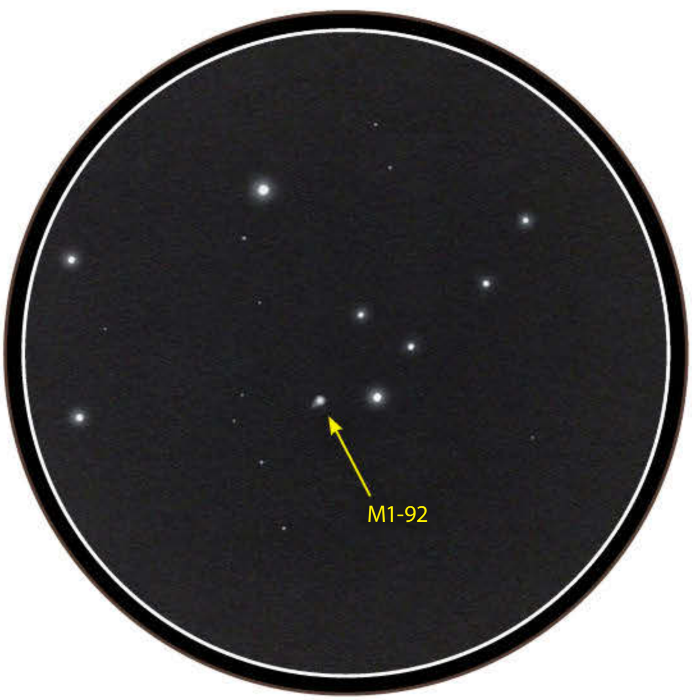
With several interesting small nebulae to choose from, I'll share two of my favorites.

Tucked within the parallelogram of the constellation Lyra is a beautiful 13th-magnitude planetary nebula, M1–64 (PK 64+15.1). At only 17" in diameter, it's often overshadowed by the more obvious Ring Nebula (M57). You can locate M1–64 nearly halfway between the Ring and Zeta (ζ) Lyrae.

Through an 8-inch telescope, it appears as a soft gray disk of uniform brightness. Its shell becomes detectable using a 12-inch scope, and when increasing the aperture to 16 inches, the nebula brightens to form a ring. Although the central star isn't visible, you should be able to spot a faint star at its north rim. This object responds well to Oxygen-III and ultra-high contrast filters.

Smaller objects require precision sketching tools. Use a ⅛" (No. 1) blending stump to apply a thin, round layer of white pastel within the star field to render the planetary's disk. If you observe the shell, add its gentle glow softly with a white pencil.

Smaller yet is Minkowski's Footprint (M1–92), a bipolar reflection nebula in the constellation Cygnus. Due to its diminutive 4.5" by 11.5" size, I used the magnitude 5.4 star 9 Cygni as a home base and then star hopped 20' north-northeast until I recognized the ladle-like star pattern in which the nebula resides. A magnitude 9.7 star lies another 1' farther north.




For the observation of tiny nebula Minkowski's Footprint (M1–92), the author used a 16-inch f/4.5 Newtonian reflector with an 8mm Plössl eyepiece and a 2.5x Barlow, for a magnification of 563x.

Looking through an 8-inch telescope, M1–92 is stellar, but it softens at 200x. You'll notice an elongation using a 12-inch scope so that it resembles a close double. Pushing the magnification of a 16-inch scope reveals its distinctive footprint appearance, though depending on sky conditions, you may not see a separation. The northwest lobe is brighter and nearly two-thirds the size of its tapered southeast component.

I drew the large circular lobe with a white pencil and then blended with a No. 1 stump. I needed only slight dabs to soften its edges while leaving the center bright. I used the residue that remained on the stump's tip to smudge in the heel.

Be sure to check out my next column for a demonstration on sketching solar prominences, and as always, feel free to share comments or questions with me at erikarix1@gmail.com. Clear skies!

# NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

## Wall clock

**Edwin Faughn**
**French Camp, Mississippi**

Space artist Edwin Faughn's *Asteroid Looming Above the Earth Seconds Before Impact* artwork graces this wall clock. Two round sizes are available with diameters of 8 and 10.75 inches (20.3 and 27.3 centimeters), as well as a square 10.75 inches on a side.

**Price: $29.95 (8-inch); $35.95 (others)**
**[e] efaughn@rainwaterobservatory.org**
**[w] www.edwinfaughn.com**


## Solar filter

**Rainbow Symphony**
**Reseda, California**

Rainbow Symphony's Black Polymer Eclipse Shades Solar Filters are a low-cost alternative to glass filters. You can use them with any optics. The material provides a yellow-orange image of the Sun and is stronger and more durable than other thin-film solar filters.

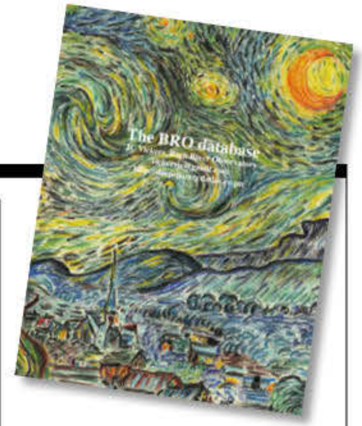
**Price: $19.95**
**[t] 800.821.5122**
**[w] www.rainbowsymphony.com**

## Scope kit

**Galileoscope, Kenosha, Wisconsin**

Galileoscope's 2-inch Refractor Telescope Kit allows anyone to assemble a 2-inch scope that provides magnifications of 25x and 50x. The kit comes with standards-based optics education and observing activities available in multiple languages.

**Price: $49.95 each, or $150 for a case of six**
**[t] 603.401.8249**
**[w] www.galileoscope.org**


## Deep-sky database

**Back River Observatory**
**Duxbury, Massachusetts**

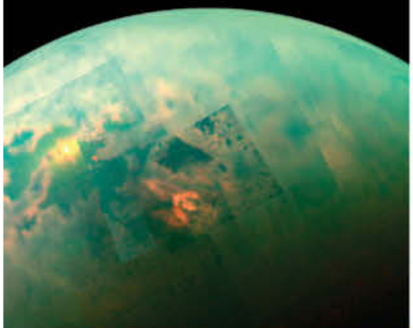
Back River Observatory's (BRO) Deep Space CCD Atlases North and South combine data and images from 2,800 mostly Palomar Observatory Sky Survey II plates. Individual field sizes range from 15' to several degrees. Visit BRO's website for free downloads.

**Price: Free**
**[t] 781.336.8344**
**[w] www.deepspaceccdatlas.eu.pn**

SEE REPORTS ON 350+ PRODUCTS AT **www.Astronomy.com/equipment.**

## COMING IN OUR NEXT ISSUE

# Secrets from TITAN'S SEAS



### What lurks in the monstrous heart of the Milky Way?

### No country for old telescopes

The fate of many classic refractors is not very bright

## PLUS

- 10 classic telescopes remembered
- 40 favorite double stars
- Around the world in eight star parties
- Turning on to the stars again
- We test Starlight Xpress' new camera

**Astronomy** magazine

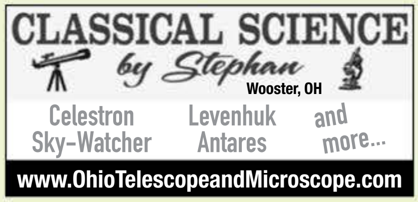
NASA/JPL-CALTECH/UNIV. OF ARIZONA/UNIV. OF IDAHO (TITAN); NASA/JPL-CALTECH/ESA/CXC/STScI (MILKY WAY); OLIVIA DRAKE/WESLEYAN UNIV. (REFRACTOR)

## INDEX *of* ADVERTISERS



The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.


OBERWERK
Astronomical binoculars and binocular telescopes at down-to-earth prices.
Astronomy 2013 Star Products
BT-100-45
BT-70-45
Available exclusively at
www.bigbinoculars.com
Toll-free 866-OBERWERK
1861 Wayne Ave., Dayton, OH 45410

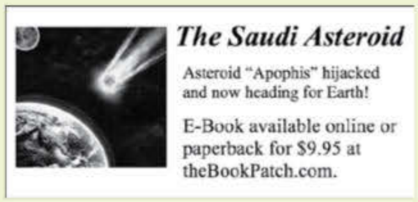

CLASSICAL SCIENCE
by Stephan
Wooster, OH
Celestron Levenhuk and
Sky-Watcher Antares more...
www.OhioTelescopeandMicroscope.com


Astrosystems
Astronomy 2015 Star Products
Advanced Truss Telescopes
Telescope Kits, ATM Supplies
Collimating Tools, Spiders, Holders
Field Covers and much more!
www.astrosystems.biz


ECLIPSE SHADES™
Safe Solar Viewers
CE Certified
SAFE FOR DIRECT SOLAR VIEWING
Rainbow Symphony, Inc.
818-708-8400 • Fax 818-708-8470
www.rainbowsymphony.com

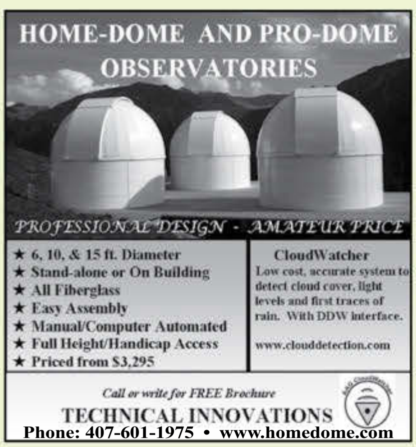

The House of Orthoscopics
The finest in Japanese oculars for those seeking exquisite lunar and planetary detail - 6" to 14" mirror cells
University Optics, Inc.
PO Box 1205
Ann Arbor, MI 48106
Universityoptics.com
734-663-2542


The Original And The Best!
OBSESSED?
Take it with you.
New UC 18" f/4.2
Ultra-Compact
fits in any car.
With the same superior quality and performance that Obsession™ 'scopes are known for.
Full line of big apertures from 12.5 to 25 inches.
See them all online.
Send for free flyer & video
PO Box 804a, Lake Mills, WI 53551 (920) 220-1195
OBSESSION TELESCOPES™
www.obsessiontelescopes.com


The Saudi Asteroid
Asteroid "Apophis" hijacked and now heading for Earth!
E-Book available online or paperback for $9.95 at theBookPatch.com.


Fine Meteorite Jewelry
In Gold & Platinum
www.JewelryDesignsforMen.com


www.Vernonscope.com
BRANDON EYEPIECES
• 6-48mm focal length
• Ultrasharp
• Superior contrast
• American made
vernonscope@gmail.com


HOME-DOME AND PRO-DOME OBSERVATORIES
PROFESSIONAL DESIGN - AMATEUR PRICE
★ 6, 10, & 15 ft. Diameter
★ Stand-alone or On Building
★ All Fiberglass
★ Easy Assembly
★ Manual/Computer Automated
★ Full Height/Handicap Access
★ Priced from $3,295
CloudWatcher
Low cost, accurate system to detect cloud cover, light levels and first traces of rain. With DDW interface.
www.clouddetection.com
Call or write for FREE Brochure
TECHNICAL INNOVATIONS
Phone: 407-601-1975 • www.homedome.com


ScopeStuff
Telescope Accessories & Hardware
World's largest inventory of telescope accessories, adapters and hardware. Free shipping in the USA!
www.scopestuff.com
512-259-9778


Bob's Knobs
Meade, Celestron, Intes, Takahashi . . . and more!
6976 Kempton Rd.
Centerville IN 47330
765-855-5109 USA
www.bobsknobs.com


OPTIC WAVE O.W.L. LABORATORIES
Optical Coatings
Parabolic Mirrors
Testing
Refiguring
www.OpticWaveLabs.com


See the Universe in color live with
MALLINCAM
Astronomical Video CCD Cameras
MALLINCAM.COM


TAKE IT ANYWHERE!
STELLARVUE
SV60EDS
60 mm f-5.5
Apochromat
STELLARVUE®
SEEING IS BELIEVING
WWW.STELLARVUE.COM
11820 KEMPER ROAD
AUBURN, CALIFORNIA 95603
(530) 823-7796


CUSTOMER SERVICE CENTER
Manage your subscription online
(Registration Required)
www.Kalmbach.com/help
• Change Address or E-mail Address
• Report Damaged or Missing Issues
• Check Expiration of Subscription
• Subscribe
• Renew Subscription
• Pay Bill
• Check Payment Status
• Newsletter Management
KALMBACH PUBLISHING CO.
For all of our publications!

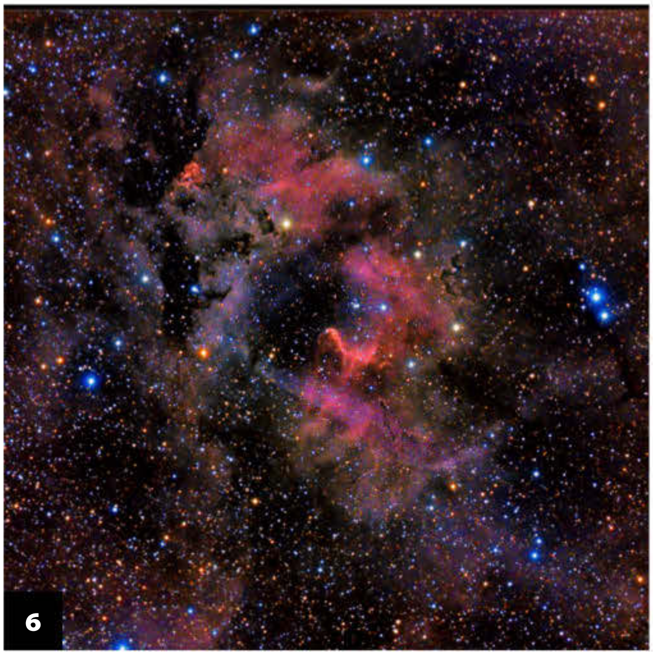
**1. STELLAR SAPPHIRES**
The Southern Pleiades (IC 2602) is a dazzling open star cluster in the constellation Carina the Keel. Some observers call it the Theta Carinae Cluster because its luminary is the magnitude 2.7 star of that name. At low power, this object looks like two clusters separated by a 0.3° gulf. (16-inch Dream Telescopes Astrograph at f/3.75, Apogee Alta U16M CCD camera, HαRGB image with exposures of 180, 30, 30, and 30 minutes, respectively)
**• *Kfir Simon***

**2. FUTURE STARS**
The region of the Taurus Molecular Cloud includes a vast amount of dust and ultra-cold gas that eventually will condense to form stars. Astronomers have found many complex molecules — organic as well as inorganic — within the cloud. (Canon 6D DSLR, Nikon 600mm f/4 ED IF lens set at f/4 and f/6, ISO 1600, two hundred and sixty 10-minute exposures, stacked)
**• *Scott Rosen***

3

4

5



6

7

**3. FORTUNATE LINEUP**
M46 is a gorgeous open cluster in the constellation Puppis. In the same line of sight — but definitely not part of the cluster — is planetary nebula NGC 2438. The stars in M46 lie 5,500 light-years away, while the planetary is some 2,500 light-years closer. (3.6-inch Astro-Tech AT90EDT refractor at f/6.7, SBIG ST-8300 CCD camera, LRGB image with exposures of 120, 40, 40, and 40 minutes, respectively) • ***Dan Crowson***

**4. UNDERWHELMING GLOB**
Observers often overlook magnitude 9.5 NGC 6366 in the constellation Ophiuchus the Serpent-bearer. It covers only as much sky as one-quarter of the Full Moon and is so sparse that it barely looks like a globular cluster at all. (10-inch Astro Systeme Austria astrograph at f/6.8, SBIG STL-11000M CCD camera, LRGB image with exposures of 75, 70, 60, and 50 minutes, respectively) • ***Ron Brecher***

**5. TRIPLE TREAT**
The crescent Moon, complete with earthshine, passed a duo of planets in February. Reddish Mars sits to our satellite's lower left while Venus shines much brighter a bit farther away. (Nikon D800E DSLR, 28-300mm Nikkor lens set at 98mm and f/5.3, ISO 6400, 0.2-second exposure, taken February 20, 2015, from Newark, California) • ***Jacques Guertin***

**6. THE DARK NIGHT**
The Bat (NGC 6995) is one of the densest parts of the eastern Veil Nebula complex in the constellation Cygnus the Swan. This supernova remnant has an apparent diameter of 3°, or an area larger than 33 Full Moons. (14-inch Officina Stellare RC-360AST Ritchey-Chrétien reflector, Apogee Alta U16M CCD camera, H$\alpha$/OIII/RGB image with exposures of 240, 150, 12, 12, and 12 minutes, respectively) • ***Bob Fera***

**7. IN A MIRROR DIMLY**
Reflection nebula van den Bergh 106 lies in the constellation Scorpius. It forms part of the vast nebulous complex in that area and surrounds the triple star Rho ($\rho$) Ophiuchi. (8-inch Officina Stellare RH200 astrograph, Quantum Scientific Instruments QSI 683wsg CCD camera, LRGB image with 2.5 hours of exposures) • ***Remus Chua***

**Send your images to:**
*Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

# BREAK THROUGH

## A once and future Sun

Roughly 7 billion years from now, the Sun will have exhausted all the hydrogen and helium in its core and ballooned into a red giant (for a second time). Then, it will puff off its outer layers to form a planetary nebula like the Medusa (Abell 21) seen here. Named after the Gorgon Medusa from Greek mythology, which famously had snakes instead of hair, the nebula's serpentine tendrils are actually the dying star's expelled gases. In this image from the European Southern Observatory's 8.2-meter Very Large Telescope, hydrogen glows red and ionized oxygen green. ESO